This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

N 3.5²: F

ARTILLERY CIRCULAR F, APRIL 25, 1893.

COURSE

OF

INSTRUCTION FOR ARTILLERY GUNNERS.

BALLISTICS,

BY

CAPTAIN JAMES M. INGALLS, FIRST ARTILLERY,

INSTRUCTOR DEPARTMENT OF BALLISTICS, UNITED STATES ARTILLERY SCHOOL, FORT MONROE, VIRGINIA,

WITH

AUXILIARY TABLES FOR SPHERICAL PROJECTILES COMPUTED BY MAJOR JOHN I. RODGERS, FIRST ARTILLERY.

PREPARED FOR PUBLICATION UNDER DIRECTION OF

MAJOR GENERAL JOHN M. SCHOFIELD, COMMANDING U. S. ARMY,

BY

CAPTAIN TASKER H. BLISS,

AID-DE-CAMP.

ADJUTANT GENERAL'S OFFICE.

1893.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1893.

Digitized by Google

Digitized by Google

ARTILLERY CIRCULAR F, APRIL 25, 1893.

COURSE

OF

INSTRUCTION FOR ARTILLERY GUNNERS.

BALLISTICS,

BY

CAPTAIN JAMES M. INGALLS, FIRST ARTILLERY,

INSTRUCTOR DEPARTMENT OF BALLISTICS, UNITED STATES ARTILLERY SCHOOL, FORT MONROE, VIRGINIA,

WITH

AUXILIARY TABLES FOR SPHERICAL PROJECTILES COMPUTED BY MAJOR JOHN I. RODGERS, FIRST ARTILLERY.

PREPARED FOR PUBLICATION UNDER DIRECTION OF

MAJOR GENERAL JOHN M. SCHOFIELD, COMMANDING U. S. ARMY,

BY

CAPTAIN TASKER H. BLISS,

AID-DE-CAMP.

ADJUTANT GENERAL'S OFFICE.

1893.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1893.

35 412SU XL 3895
10/06 31150-119 UA

Digitized by Google

Digitized by Google

ARTILLERY CIRCULAR F.

HEADQUARTERS OF THE ARMY,
ADJUTANT GENERAL'S OFFICE,
Washington, April 25, 1893.

The following course of instruction in ballistics, for artillery gunners, by Captain James M. Ingalls, First Artillery, is published for the use and information of all concerned.

BY COMMAND OF MAJOR GENERAL SCHOFIELD:

R. WILLIAMS,
Adjutant General

OFFICIAL:

Assistant Adjutant General.

Digitized by Google

Digitized by Google

TABLE OF CONTENTS.

CHAPTER I.

Figure representing the travel of a projectile, 7. Definitions, 7. Relation between horizontal range and striking velocity for small angles of elevation, 8. Use of Table I, 8. Ballistic coefficient, 9. Resistance of the air, 11. Coefficient of reduction, 11. Practical applications, 11. Interpolation, 12. Examples of interpolation, 13. Practical examples, 14. Table of ballistic data for field, siege, and seacoast guns adopted by the United States, 14. Use of Table II, 16. Application of logarithms to the solution of ballistic problems, 16. Energy of a projectile, 19. Ballistic effects of atmospheric conditions, 22. Use of Table III, 22.

CHAPTER II.

Angle of elevation, 25. Angle of departure, jump, 25. Formula for small angles of departure, 25. Trajectory in a vacuum, 29. Trajectory in air, 29. Angle of fall, 30. Velocity of projectile at summit of trajectory for small angles of departure, 31. Horizontal distance from muzzle of gun to summit of trajectory, 33. Highest flight of trajectory, 33. Flatness of trajectory, 36. Modification of formulas for extended ranges, 37. Auxiliary tables, 39. Use of Table A, 40. Interpolation formulas for Table A, 42. Table B for angles of fall, 45. Use of Rodgers' auxiliary tables for spherical projectiles, 48. Drift of elongated projectiles, 48. Range tables, 50. Partial range table for the 8-inch converted rifle, 50. Correction of range table for variations of muzzle velocity, 52. Correction of range table for variations in the value of the ballistic coefficient, 53.

TABLE I.—Ballistic table for ogival-headed projectiles 55
Auxiliary A 80
Auxiliary B 88
TABLE II.—For spherical projectiles 97
Auxiliary A 103
Auxiliary B 112
Auxiliary M 121
TABLE III.—Values of $\frac{\delta}{\delta'}$ for temperature and pressure of atmosphere two-thirds saturated with moisture 131

Digitized by Google

Digitized by Google

COURSE OF INSTRUCTION FOR ARTILLERY GUNNERS.

BALLISTICS.

CHAPTER I.

It is well known to anyone who has performed the duties of gunner at target practice with seacoast guns, that in order to hit a distant object it is necessary to elevate the muzzle of the gun, and that the farther the target the more must the muzzle be elevated. The gunner also knows, by watching the projectile in its flight, that, on account of the upward direction given to it by the elevation of the muzzle, it does not pursue a direct course to the target. He sees it ascend above the level of the gun while moving swiftly forward and then descend in its forward motion until, if it was skillfully started, it hits the target. The form of the path described by the projectile in its flight through the air is not apparent to an observer standing in the rear of the gun, which is the only place from which the projectile can be seen at all. To such an observer the projectile appears to move up an inclined plane to its highest point, and then down another to the target. If, however, he has observed the beautiful curves described by a slower moving base ball he can form a very correct idea of this path. In Fig. 1, AEF represents the travel of a projectile in passing from the gun

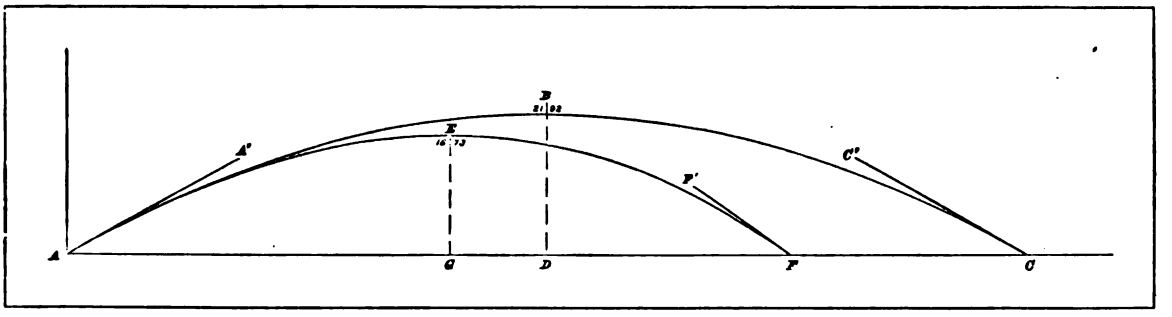

FIG. 1.

at A to the target at F. AA′ is the direction of the axis of the gun when fired with reference to the horizontal line AF. This figure will be described more fully in Chapter II.

Definitions.—The curved path described by a projectile in the air, AEF, is called its *trajectory*. It is divided into two branches, with the point of division at E, the highest point reached by the projectile. AE is called the *ascending branch*, and EF the *descending branch*. The point E, where the projectile ceases to ascend, and begins to descend, is called the *summit* of the trajectory.

The *horizontal range*, AF, is the horizontal distance from the gun, A, to the point of fall, F.

Muzzle velocity is the velocity the projectile has when it leaves the piece. It is sometimes called initial velocity, or velocity of projection. This is the greatest velocity the projectile has at any point of its flight.

Digitized by Google

Striking velocity is the velocity of the projectile at the point of fall, F. It is therefore the velocity at the far end of the horizontal range.

Remaining velocity is the velocity at any point of the trajectory between A and F. The remaining velocity at E is called *summit velocity.*

Angle of elevation is the elevation of the muzzle or axis of the piece, expressed in circular measure, that is, in degrees and minutes of arc. It is the angle A′AF in the figure. If the axis of the piece be level, pointing in the direction AF, there is no elevation, or the elevation is said to be 0°. If the gun should be revolved in its trunnions until its axis is vertical or points directly upward (were this possible) the elevation would be 90°, or a quadrant. The elevation represented in the figure (AA′) is 30°, or one-third of a quadrant. High-power guns will rarely be elevated more than one-fourth of this angle.

A little reflection will convince the learner that, the muzzle velocity remaining the same, the shorter the horizontal range the smaller will be the angle of elevation and the flatter the trajectory. This is so fully and clearly illustrated by the great variety of trajectories witnessed in a game of base ball as to be apparent to all. Now it has been clearly proven that when the angle of elevation does not exceed about 5° (that is, one-sixth of the elevation of AA′), the curvature (or bending) of the trajectory need not be considered in our calculations; but for practical purposes the trajectory may be taken to coincide with the horizontal range, AF.

This simplifies matters greatly, and for this reason all the examples of this chapter will be so selected that the curvature of the trajectories may be neglected.

Relation between horizontal range and striking velocity for small angles of elevation.—To fix the ideas suppose we consider the following example:

Example 1.—The 8-inch converted rifle fires an oblong projectile weighing 180 pounds, with a muzzle velocity of 1400 f. s. Determine the horizontal range for which the striking velocity is reduced to 1300 f. s. Also compute the time of flight.

In this example we have given the following data:

Diameter of projectile (d) = 8 inches.
Weight of projectile (w) = 180 pounds.
Muzzle velocity of projectile (V) = 1400 foot-seconds.
Striking velocity of projectile (v) = 1300 foot-seconds.

From these four given numbers we are required to find the horizontal range (X) and time of flight T.

Solution.—Turn to Table I and find in the velocity column (which is the first, or left-hand, column and headed u)* the given striking velocity (1300), which will be found near the middle of page 58. Take out the number in the second column, (headed $S(u)$), on the same horizontal line, which is 5399.2. Next look for the given muzzle velocity (1400) in the velocity column and take out the corresponding space number in the $S(u)$ (or space) column, which is 4878.6. Subtract this last from the former space number, multiply the remainder by the number representing the weight (in pounds) of the projectile, and divide the product by the square of the number expressing the diameter (in inches) of the projectile. The quotient will be the range required in feet. These numerical operations are indicated as follows:

$$X = \frac{180}{64}\{5399.2 - 4878.6\}.$$

Actually performing these operations, we find

$$X = 1464 \text{ ft.} = 488 \text{ yds.}$$

---

*The reason for employing u instead of v in Tables I and II will be given in Chapter II.

Digitized by Google

For the time of flight we take our numbers, corresponding to the given velocities, from the $T(u)$ (or time) column, and proceed exactly as explained for the range. Thus

$$T = \frac{180}{64}\{2.900 - 2.514\};$$

whence, by simple arithmetic, we find

$$T = 1.09 \text{ sec.}$$

These answers mean that the projectile for the 8-inch converted rifle will have its velocity reduced from what it was at the muzzle of the gun, namely, 1400 f. s., to 1300 f. s.; that is, it loses 100 feet per second of velocity, while it moves over a horizontal range of 488 yards, and that the time required for this motion is 1.09 seconds. Most gunners would know without being told that for the short range of 488 yards the gun should be but slightly elevated, and that the projectile in its flight would rise but little above the level of the gun. We shall be able to show in the second chapter that the required elevation is less than one degree, or less than $\frac{1}{90}$ of a quadrant; and that the greatest height of the projectile above the muzzle is about 4¾ feet, or less than $\frac{1}{800}$ of the range. The loss of velocity which the projectile suffers while moving over this short range is caused almost entirely by the resistance of the air, which to rapidly moving bodies, like a cannon ball, is very great.

It will be seen from the above numerical work that the calculation of a range or time of flight under the given conditions requires but three simple arithmetical operations in each case, namely, one subtraction, one multiplication, and one division. The chief part of the work was performed once for all when the space and time numbers were computed and tabulated. The numbers in the ballistic tables must be taken for granted, as it is not within the scope of this work to enter upon the subject of their calculation. It is to be hoped, however, that the learner will be able to use these tables easily and intelligently, when he shall have completed the course.

The rule we have given above for computing the range may be expressed much more concisely and in a form more easily remembered, by employing algebraic symbols. Thus the rule is condensed into the following symbolic form:

$$X = \frac{w}{d^2}\{S(v) - S(V)\} \text{ ..... (1).}$$

The learner is advised to compare equation (1) with the verbal rule until he is satisfied that they mean the same thing. The symbols $S(v)$ and $S(V)$ are called *space functions* of the velocity, for the reason that they change value or *vary* as the velocity *varies*, as is clearly seen by examining Table I.* It will also be seen that these space functions *increase* in numerical value while the velocities in the first column of the table *decrease;* and this is the reason why, in the above formula, $S(v)$ (the space function of the striking velocity) precedes $S(V)$ (the space function of the muzzle velocity). That is, the striking velocity being always less than the muzzle velocity, its space function, in the arrangement of our table, is the greater, and is that from which the space function of the muzzle velocity is to be subtracted.

For the time of flight, expressed in algebraic symbols, we have

$$T = \frac{w}{d^2}\{T(v) - T(V)\} \text{ ..... (2).}$$

The symbols within the braces are called *time functions* of the velocity; and the same remarks are applicable to them as to the space functions.

Ballistic coefficient.—The factor (or multiplier) $\frac{w}{d^2}$ by which the differences of the space and time functions in Equations (1) and (2) are multiplied, is a very important factor, enter-

* The reason for employing u instead of v in Tables I and II will be given in Chapter II.

Digitized by Google

ing into all ballistic formulas. It is called the *ballistic coefficient*, and is represented by the capital letter *C*, abbreviation of coefficient. That is, we have

$$C = \frac{w}{d^2} \quad \ldots\ldots (3).$$

Making this substitution, the expressions for horizontal range, and time of flight for small angles of elevation, take the usual forms:

$$X = C\{S(v) - S(V)\} \quad \ldots\ldots (4).$$

$$T = C\{T(v) - T(V)\} \quad \ldots\ldots (5).$$

An examination of Equation (4) will show that for the same muzzle and striking velocities the range of a projectile depends upon the value of the ballistic coefficient *C*, increasing or decreasing as this factor increases or decreases. In a vacuum or empty space all bodies, whether a feather or a leaden bullet, projected alike, would attain the same horizontal range, and their striking velocities would all be the same and equal to their initial velocities. But it has been shown by numerous experiments that the actual striking velocity at the end of any horizontal range is always less than the initial velocity. This fact indicates a resistance which the projectile encounters (the resistance of the air), and which robs the projectile of a portion of its motion, thus diminishing its velocity, and, therefore, shortening the range. It follows, then, from Equation (4) that the ballistic coefficient *C* measures the ability of a projectile to overcome the resistance of the air; or, we may say, in short, that it measures the *ballistic efficiency* of a projectile. It is therefore important that this factor, which depends entirely upon the projectile, should be as large as possible.

From Equation (3) it will be seen that *C* may increase in two ways—by increasing the value of w or diminishing that of d^2.

1. *The ballistic efficiency of a projectile may be increased by increasing its weight, other things being equal.* The principle involved in this statement is verified by every-day experience. The base ball player, for example, knows that he can throw the standard ball further than he can a light cotton ball of the same size and smoothness, though he is able to give to both the same initial velocity; and all gunners know that an oblong projectile will range further than a spherical shot of the same diameter and having the same muzzle velocity; and this, chiefly, because of the greater weight of the former.

As all modern heavy projectiles are made of substantially the same kind of material, the only practical way to increase their weight is to lengthen them; and in the last few years we have seen oblong projectiles increase from 2 or 2½ calibers to 3, 3½, and even to 5 calibers in length.

2. It has been proven by many experiments (and, indeed, seems self-evident) that the resistance of the air to the motion of a projectile depends upon the area which the projectile presents to the air in the direction of motion, that is, upon the area of its greatest cross section normal to the direction of motion. As a modern oblong projectile moves very nearly point foremost the area which it presents for the resistance of the air is, for all practical purposes, the area of its base; and, therefore, the ballistic efficiency of a projectile is the greater the less this area is, other things being equal. But as the base of a projectile is a circle, its area varies as the square of its diameter, or as d^2. It will now be apparent why, in the expression for the ballistic efficiency of a projectile, its weight enters as a multiplier and the area of its base (represented by d^2) as a divisor. The expression $\frac{w}{d^2}$ is also called the *sectional density* of the projectile, because, as is readily seen, it represents the weight of metal per square inch of cross section.

Digitized by Google

Resistance of the air.—We have just seen that the amount of resistance a projectile encounters in moving through the air increases with the area exposed to the resistance, that is, to the square of the diameter of the projectile. The resistance also increases as the square of the velocity with which the projectile is moving at any instant for all velocities greater than about 1330 f. s. This has been proven by experiment—notably by the experiments conducted by Professor Bashforth, at Shoeburyness, England, a few years ago, and by the proof firings at the Krupp establishment in Prussia. The amount of resistance offered by the air to a projectile, moving with any given velocity, is the most important element in the construction of ballistic tables, like Table I From a discussion of the published results of Professor Bashforth's experiments with oblong projectiles, the following expression for the resistance of the air in pounds (abbreviated to R_a), for velocities greater than 1330 f. s., was deduced by the author and published in his work on Exterior Ballistics, page 36:

$$R_a = 0.00000441 8 d^2 v^2 \text{ .....(6).}$$

Other expressions for the resistance, for velocities less than 1330 f. s. have also been deduced, but are omitted here, as we shall have no use for them in what follows.

A consideration of Equation (6) is very instructive. If we assume (what is approximately correct) that it expresses the resistance for small velocities also, and make $d = 12$ inches, and $v = 1$ foot per second, we shall have, approximately,

$$R_a = 0.00000441 8 \times 144 = 0.000636192 \text{ pounds,}$$

a resistance which is scarcely perceptible in its effects. But suppose the projectile to be moving with a velocity of 2000 f. s., we must now multiply the above resistance by $(2000)^2$ or 4000000; and the resulting resistance, or pressure, is found to be 2545 pounds—a resistance which would rapidly diminish the velocity of even the heaviest projectile.

Coefficient of reduction.—Professor Bashforth's experiments, upon which the value of the numerical factor in Equation (6) depends, were made with projectiles very similar to those used with our 8-inch converted rifle; that is, they had rather blunt heads, and were neither as well made nor as well centered in the gun as our sharper pointed modern projectiles. We should conclude from this that the expression for the resistance for these latter projectiles, though retaining the form of Equation (6), would have a smaller numerical coefficient; and experiments have abundantly verified this conclusion. In fact, it has been found that this coefficient should be reduced about 10 per cent; or, what is the same thing, multiplied by 0.9 in order to express correctly the resistance opposed by the air to the motion of our modern projectiles. Table I was, however, computed with the coefficient furnished by Bashforth's experiments, and answers perfectly for projectiles similar to those he employed. The table can also be used for the modern projectiles by multiplying d^2 by 0.9, since it is evident that, in Equation (6), it is immaterial whether we apply the multiplier 0.9 (called the coefficient of reduction), to the numerical coefficient, or to d^2, so far as the value of R_a is concerned. The ballistic coefficient for the modern projectiles becomes, then, adopting this latter course,

$$C = \frac{w}{0.9\, d^2} \text{ .....(7).}$$

Practical applications.—There are four quantities entering into Equation (4), namely, horizontal range, ballistic coefficient, space function of striking velocity and space function of muzzle velocity—represented, respectively, by the symbols X, C, $S(v)$, and $S(V)$. These four quantities are so related to each other in Equation (4) that, any three of them being given, the fourth can easily be determined by simple algebraic transformations, in which the required

Digitized by Google

quantity is brought by itself to the left member of the equation. Thus, in addition to the expression for X, we may have the following:

$$S(v) = \frac{X}{C} + S(V) \text{.....(8).}$$

$$S(V) = S(v) - \frac{X}{C} \text{.....(9).}$$

$$C = \frac{X}{S(v) - S(V)} \text{.....(10).}$$

Interpolation.—It will be seen that Equations (8) and (9) do not give the striking and muzzle velocities directly, but only the space functions of those velocities. The velocities themselves must be taken from the first column of Table I, on the same lines as the given space functions in the second column. Thus, suppose an application of Equation (8) had resulted in giving $S(v)$ equal to 10842.5, what is the required striking velocity? We look along the $S(v)$ column of Table I, until on page 69, we find the given space function, and alongside of it in the u column we find 810, the velocity required—*always in feet per second.* Similarly, if from Equation (9) we had found $S(V) = 4393.0$; Table I, page 57, would give us $V = 1500$ f. s. In both these illustrative examples we have found the given space functions in the table, but this rarely, if ever, happens in practice. We shall almost invariably find that our space functions deduced from Equations (8) and (9) lie each between two consecutive tabular space functions, and of course the velocities we seek will lie, in each case, between the corresponding tabular velocities. Suppose, for example, we have found $S(V) = 4407.1$. We find in Table I, page 57, that this space function lies between 4393.0 and 4416.5, and therefore V must lie between 1500 f. s. and 1495 f. s. How shall we determine the exact value of V? Arrange the given space function, the required velocity, and the tabular numbers between which they lie, as follows:

v.	$S(v)$.
$5\left\{\begin{matrix}1500\\ V\\ 1495\end{matrix}\right\}2$	$9.4\left\{\begin{matrix}4393.0\\ 4407.1\\ 4416.5\end{matrix}\right\}23.5$

The difference between the two tabular velocities is 5, and between the tabular space functions, 23.5. Also, the difference between the given space function and the greater of the two tabular space functions is 9.4. Now, if a difference of 23.5 between two space functions corresponds to a difference of 5 in the velocities, what will a difference of 9.4 between two space functions correspond to? This evidently gives the proportion

$$23.5 : 9.4 :: 5 : 2.$$

We therefore have

$$V = 1495 + 2 = 1497 \text{ f. s.}$$

This proportion furnishes the following rule for taking from Table I a velocity corresponding to a given space function, and applies as well to all the other functions found in the table:

Multiply the difference between the given function and the next greater tabular function by the tabular velocity difference, and divide the product by the tabular function difference. Add this quotient to the lesser of the two tabular velocities, and the sum is the velocity required. This rule may be expressed much more concisely by employing algebraic symbols, as in the case of Equations (1) and (2), as follows:

Digitized by Google

Designate by v the required velocity and by v_1 and v_2 (read "v sub one" and "v sub two"), the consecutive tabular velocities between which v lies. Then $S(v)$, $S(v_1)$, and $S(v_2)$ (all known) will denote the corresponding space functions. Also let $v_1 - v_2 = h$, and $S(v_2) - S(v_1) = d_1$. Then we shall have, as an equivalent of the above rule,

$$v = v_2 + \frac{h}{d_1}\{S(v_2) - S(v)\} \text{.....(11).}$$

The values of d_1 (without the decimal point, which must be supplied) are given in the third column of Table I. The velocity difference h has different values in different parts of the table, but can be determined by a glance at the velocity column.

If a *velocity* not in Table I is given and we wish to find its space function, we solve Equation (11) with reference to $S(v)$. Thus

$$S(v) = S(v_2) - \frac{d_1}{h}(v - v_2) \text{.....(12).}$$

It will be readily understood that Equations (11) and (12) are as applicable to the other functions of Table I as to the space functions; that is, to the time functions $T(v)$, already considered, and to the altitude function $A(v)$, and inclination function $I(v)$, which will be taken up in the next chapter.

Examples of interpolation.—Compute the values of v corresponding to the following functions of Table I:

1. $S(v) = 2537.2$. 2. $A(v) = 138.42$. 3. $I(v) = 0.11498$. 4. $T(v) = 8.327$.

ANSWERS.

1. $v = 1950 + \frac{10}{36.0}(2546.4 - 2537.2) = 1950 + 2.6 = 1952.6$ f. s.

2. $v = 1460 + \frac{5}{2.40}(139.77 - 138.42) = 1460 + 2.8 = 1462.8$ f. s.

3. $v = 1254 + \frac{2}{.00048}(.11527 - .11498) = 1254 + 1.2 = 1255.2$ f. s.

4. $v = 815 + \frac{1}{.025}(8.333 - 8.327) = 815 + 0.24 = 815.24$ f. s.

Find the following functions from Table I, by means of Equation (12):

$S(763.64)$. $A(1216.7)$. $I(1573.8)$. $T(1857.3)$.

ANSWERS.

$S(763.64) = 11848.9 - 22.2 \times 0.64 = 11848.9 - 14.2 = 11833.9.$

$A(1216.7) = 269.79 - \frac{1.55}{2} \times 0.7 = 269.79 - 0.54 = 269.25.$

$I(1573.8) = .06296 - \frac{.00058}{5} \times 3.8 = .06296 - .00044 = .06252.$

$T(1857.3) = 1.291 - \frac{.021}{10} \times 7.3 = 1.291 - .015 = 1.276.$

The learner is advised to practice himself in the use of the interpolation formulas (Equations (11) and (12)), until he is thoroughly familiar with their use.

Digitized by Google

Practical examples.—We will conclude this chapter with a number of examples of the use of the formulas which have been given. The data will relate to the 8-inch converted rifle, the 10-inch and 15-inch smooth-bore guns, and the field, seige, and seacoast guns which have been adopted by the Government but not yet in service (with the exception of the 3.2-inch field gun). But to save repetition in these and subsequent examples, we will first give a table of such ballistic data relating to these guns as we shall require in the course of the work. The data relating to the new guns is taken from a much larger table issued from the Ordnance Office, Washington, and bearing date June 15, 1892. These latter guns are all steel breech loaders.

In the last two columns are given, for convenience, the ballistic coefficient and its logarithm for each gun. These may be regarded as so many examples, and should be verified by the student.

BALLISTIC DATA OF FIELD, SIEGE, AND SEACOAST GUNS ADOPTED BY THE UNITED STATES.

BREECH-LOADING STEEL RIFLES.

Caliber of gun (d).	Kind of powder.	Weight of charge, lbs.	Weight of projectile, lbs. (w).	Muzzle velocity, f. s. (V).	Coefficient of reduction.	Ballistic coefficient, C.	Log C.
3.2-inch B. L. rifle	Sphero-Hex	3.5	13.5	1685	0.9	1.4648	0.16579
3.6-inch B. L. rifle	Sphero-Hex	4.1875	20	1550	0.9	1.7147	0.23418
5-inch B. L. rifle	Sphero-Hex	12.5	45	1830	0.9	2.0000	0.30103
8-inch B. L. rifle	Brown Pris	125	300	1950	0.9	5.2083	0.71670
10-inch B. L. rifle	Brown Pris	250	575	1975	0.9	6.3889	0.80543
12-inch B. L. rifle	Brown Pris	520	1000	2100	0.9	7.7160	0.88740
16-inch B. L. rifle	Brown Pris	1060	2370	1975	0.9	10.2865	1.01227

MUZZLE-LOADING RIFLE AND SMOOTH-BORE GUNS.

8-inch rifle, converted	Sphero-Hex	35	180	1414	1.0	2.8125	0.44909
10-inch S. B., $d = (9.87)$	Cannon	20	128 shot. 107 shell.	1358 1493	1.0	1.3139 1.0984	0.11857 0.04075
15-inch S. B., $d = (14.87)$	Mammoth	100 60	450 shot. 343 shell.	1534 1450	1.0	2.0351 1.5512	0.30859 0.19067

Example 2.—Compute the striking velocity and time of flight of a service projectile fired from the 8-inch converted rifle for each of the following ranges: 1200, 1400, 1600, 1800, and 2000 yards.

Remarks.—The unit of distance or range used in computing Table I is the foot. Therefore, when the range is given in yards, as is habitually the case in practice, it must be first reduced to feet before solving any example requiring the use of Table I or II.

The learner should keep all his solutions for use in subsequent examples.

Solution of Example 2 for $X = 1200$ yards $= 3600$ feet.

In solving this example we use Equations (8) and (5) in the order named. Substituting given numbers in these equations, we have

$$S(v) = \frac{3600}{2.8125} + S(1414),$$

and

$$T = 2.8125 \left\{ T(v) - T(1414) \right\}.$$

Digitized by Google

The operations may be arranged as follows:

$$\frac{3600}{2.8125} = 1280.0$$
$$S(1414) = 4808.6$$
$$S(v) = 6088.6 \quad \therefore \quad v = 1184.6 \text{ f. s.}$$

$$T(1184.6) = 3.456$$
$$T(1414) = 2.464$$
$$2.8125 \times 0.992 = 2.79 \text{ sec} = T.$$

The striking velocities and times of flight for the other given ranges are as follows:

Range, in yards, X.	Striking velocity, v.	Time of flight, T.
1400	1152.9 f. s.	3.30 sec.
1600	1122.8	3.83
1800	1095.3	4.37
2000	1070.8	4.93

Example 3.—The observed times of flight of service projectiles fired from the 8-inch converted rifle were as follows: 2.75, 3.25, 3.8, 4.5, and 5 seconds. What was the striking velocity and range in each case?

Solution.—From Equation (5), by simple algebraic transformations precisely similar to those already employed in deducing Equation (8) from Equation (4), we have

$$T(v) = \frac{T}{C} + T(V) \quad \text{.....(13).}$$

By means of this equation we calculate the striking velocity by aid of the time functions and the range by Equation (4). For $T = 2.75$ seconds, we have

$$T(v) = \frac{2.75}{2.8125} + T(1414)$$

and

$$X = 2.8125 \{S(v) - S(1414)\}.$$

Arranging the operations as before, we have

$$\frac{2.75}{2.8125} = 0.978$$
$$T(1414) = 2.464$$
$$T(v) = 3.442 \quad \therefore \quad v = 1187.1 \text{ f. s.}$$

$$S(1187) = 6071.9$$
$$S(1414) = 4808.6$$
$$2.8125 \times 1263.3 = 3553 \text{ ft.} = 1184 \text{ yds.}$$

Remarks.—In dividing the range, or time, by C, carry the division to as many decimals as there are in the corresponding tabular function, and no further.

Take out velocities corresponding to given tabular functions to the nearest tenth of a foot.

Compute ranges to the nearest foot, and times of flight to the nearest hundredth of a second.

Digitized by Google

The other answers to Example 3 are as follows:

T.	v.	X.
3.25 sec.	1156.0 f. s.	4139 ft.
3.80	1124.5	4765
4.50	1089.4	5538
5.00	1067.9	6076

Example 4.—At what range will a service projectile fired from the 8-inch B. L. R. have the same striking velocity as a service projectile fired from the 8-inch converted rifle has at 1500 yards? Also, compute the striking velocity.

Solution.—The learner should have no difficulty in seeing that the two operations required to solve this example are the following, employing Equations (8) and (4) in the order named.

1. Striking velocity for each projectile.

$$S(v) = \frac{4500}{2.8125} + S(1414) = 6408.6 \quad \therefore \quad v = 1137.6 \text{ f. s.}$$

2. Range of 8-inch B. L. R. projectile.

$$X = 5.2083 \left\{6408.6 - S(1950)\right\} = 20115 \text{ ft.}$$

The range required is, therefore, 6705 yards, or more than four times the range of the feebler projectile.

Example 5.—Compute the striking velocity and time of flight of a solid shot fired from the 15-inch S. B. gun for a horizontal range of 1700 yards. For the necessary data consult the table on page 14.

In solving this example we must use Table II *for spherical projectiles.* The general form of this table is the same as Table I and needs no special description. We have

$$S(v) = \frac{5100}{2.0351} + S(1534) = 2506 + 1303 = 3809 \quad \therefore \quad v = 965 + 4.2 = 969.2 \text{ f. s.}$$

$$T = 2.0351 \left\{T(969.2) - T(1534)\right\} = 2.0351 \left\{2.849 - 0.767\right\} \quad \therefore \quad T = 4.24 \text{ sec.}$$

Application of logarithms to the solution of ballistic problems.—It will be assumed that the learner knows how to use a table of logarithms and has been taught the rules for their numerical applications. These latter may be briefly stated as follows: Let N and n be any two numbers, whole or fractional. Then

$$\log (Nn) = \log N + \log n \text{.....(14)}$$

$$\log \left(\frac{N}{n}\right) = \log N - \log n \text{.....(15)}$$

$$\log (N^n) = n \log N \text{.....(16)}$$

$$\log (N^{\frac{1}{n}}) = \frac{1}{n} \log N \text{.....(17);}$$

that is, by the use of logarithms, multiplication is reduced to addition, division to subtrac-

Digitized by Google

tion, involution to multiplication, and evolution to division. The last two expressions involving involution and evolution, are frequently combined in one. Thus, if $\frac{x}{y}$ represents any fraction, proper or improper (for example $\frac{3}{4}$, $\frac{9}{5}$, etc.), then

$$\log\ (N^{\frac{x}{y}}) = \frac{x}{y} \log N \text{.....(18).}$$

These rules will all be sufficiently illustrated in the course of the work. We add a few examples for practice and instruction.

Example 6.—Divide 7683 by 7.716, carrying the quotient to two decimals only.

OPERATION.

$$\log\ 7683 = 3.88553$$
$$\log\ 7.716 = 0.88739$$
$$\log\ 995.72 = 2.99814$$

The quotient required is, therefore, 995.72.

Remark.—We can take with accuracy only as many figures from the table as there are decimals in the mantissa of the tabular logarithm. Therefore with a 5-decimal table we can get only five figures in our answers—enough, however, for all practical purposes.

Example 7.—Multiply together 7.843 and 198.7 and divide the product by 14.96.

Here we have a combination of multiplication and division, and to obtain the logarithm of the answer we add together the logarithms of the numbers to be multiplied and from the sum subtract the logarithm of the divisor. Thus

$$\log\ 7.843 = 0.89448$$
$$\log\ 198.7 = 2.29820$$
$$\log \text{ of product} = 3.19268$$
$$\log\ 14.96 = 1.17493$$
$$\log\ 104.17 = 2.01775 = \log \text{ of quotient.}$$

That is,

$$\frac{7.843 \times 198.7}{14.96} = 104.17\,.$$

Example 8.—Divide the product of 0.00642 and 8.249 by the product of 0.7637 and 73.96, carrying the quotient to five decimals.

Calling the required quotient x, we may state this example as follows: Find the numerical value of x in the expression

$$x = \frac{0.00642 \times 8.249}{0.7637 \times 73.96.}$$

In this case we have two multiplications to perform and one division. The operations are as follows:

$$\log\ 0.00642 = 7.80753-10 \qquad \log\ 0.7637 = 9.88292-10$$
$$\log\ 8.249 = 0.91640 \qquad \log\ 73.96 = 1.86899$$
$$\log \text{ numerator} = 8.72393-10 \qquad \log \text{ denominator} = 1.75191$$
$$\log \text{ denominator} = 1.75191$$
$$\log \text{ quotient} = 6.97202-10$$

Therefore, $x = 0.0009376$; or, to five decimals, $x = 0.00094$.

Digitized by Google

By employing the arithmetical complement (with which the learner is supposed to be familiar), the above operation becomes as follows:

$$\begin{aligned}
\log 0.00642 &= 7.80753-10\\
\log 8.249 &= 0.91640\\
\text{a. c. } \log 0.7637 &= 0.11708\\
\text{a. c. } \log 73.96 &= \underline{8.13101-10}\\
\log 0.00094 &= \overline{6.97202-10}
\end{aligned}$$

Example 9.—Find the numerical value of d in the following expression:

$$d = \frac{(14.87)^3 \times 180 \times 20358}{450 \times 64 \times 14208}$$

OPERATION.

$$\begin{aligned}
3\log 14.87 &= 3.51693\\
\log 180 &= 2.25527\\
\log 20358 &= 4.30874\\
\text{a. c. } \log 450 &= 7.34679-10\\
\text{a. c. } \log 64 &= 8.19382-10\\
\text{a. c. } \log 14208 &= \underline{5.84747-10}\\
\log 29.446 &= 1.46902 = \log d.
\end{aligned}$$

Remark.—In subtracting the logarithm of a divisor from 10 to obtain its arithmetical complement, begin at the left and subtract each figure successively toward the right from 9 until the last figure is reached, which subtract from 10.

This is evident since we have

$$10 = 9.9999\,(10).$$

By this method the arithmetic complement of a logarithm may be written down as easily as the logarithm itself.

Example 10.—According to Captain de Marre, of the French Naval Artillery, the thicknesses of steel plate which similar projectiles of the same diameter and weight will penetrate, are proportional to the $\frac{1}{7}^{0}$ powers of the velocities. If with a velocity of 1975 f. s. a 10-inch projectile will penetrate 20.4 inches, how many inches would it penetrate with a velocity of 1500 f. s.?

We have, according to de Marre,

$$(1975)^{\frac{1}{7}} : (1500)^{\frac{1}{7}} :: 20.4 : x$$

$$\therefore x = 20.4\left(\frac{1500}{1975}\right)^{\frac{1}{7}}$$

$$\begin{aligned}
\log 1500 &= 13.17609-10\\
\log 1975 &= \underline{3.29556}\\
&\quad 9.88053-10
\end{aligned}$$

$$10 \times (9.88053-10) = 98.80530-100 = 8.80530-10$$

$$(8.80530-10) \div 7 = (68.80530-70) \div 7 = 9.82933-10$$

$$\begin{aligned}
\log 20.4 &= \underline{1.30963}\\
\log 13.77 &= 1.13896.
\end{aligned}$$

The projectile would therefore penetrate 13.77 inches.

Example 11.—Captain de Marre's expression for the penetration of steel plates, when the projectile strikes the plates normally, is as follows:

$$e = \left\{[6.99066-10]\frac{wh^{\frac{1}{2}}}{d^2}\right\}^{\frac{1}{7}} \text{.....(19)}$$

Digitized by Google

in which e is the depth of penetration in inches. The number inclosed in square brackets is the logarithm of a constant multiplier, that is of the number 0.0009787, by which the function of the diameter, weight and velocity of the projectile is to be multiplied. Its logarithm is given for the convenience of the computer. Expressed in logarithms this formula becomes, by application of Equations (14)–(18),

$$\log e = \frac{10}{7}\left\{6.99066 - 10 + \frac{1}{2}\log w + \log v - \frac{3}{4}\log d\right\} \quad \text{.....(20).}$$

The learner will observe how all the formidable operations expressed in Equation (19) are reduced to the simplest arithmetical calculations by the application of logarithms, and the laborious work of many hours reduced to not more than five minutes.

For a numerical application compute the value of e for the muzzle velocity of a service projectile fired from the 12-inch B. L. R. The operation will be arranged as follows:

$$\begin{aligned}
\text{Constant } \log &= 6.99066 - 10 \\
\tfrac{1}{2}\log 1000 &= 1.50000 \\
\log 2100 &= \underline{3.32222} \\
&\quad 1.81288 \\
\tfrac{3}{4}\log 12 &= \underline{0.809385} \\
&\quad 1.003495 \\
&\quad\quad 10 \\
&\quad 7\overline{)10.03495} \\
\log e &= 1.43356 \quad \therefore \quad e = 27.14 \text{ inches.}
\end{aligned}$$

Example 12.—Compute the striking velocity and time of flight of a service projectile fired from the 3.6-inch field gun, for a range of 2000 yards.

$$\begin{aligned}
\log 6000 &= 3.77815 \\
\log C &= \underline{0.23418} \\
\log 3499.2 &= 3.54397 \\
S(V) &= \underline{4162.2} \\
S(v) &= 7661.4 \quad \therefore \quad v = 1004.5 \text{ f. s.} \\
T(v) &= 4.912 \\
T(V) &= \underline{2.027} \\
\log 2.885 &= 0.46014 \\
\log C &= \underline{0.23418} \\
\log T &= 0.69432 \quad \therefore \quad T = 4.95 \text{ sec.}
\end{aligned}$$

Energy of a projectile.—By the energy of a projectile in motion is meant its power to do work, that is to overcome an obstacle such as the resistance of the air, to penetrate the side of an armored ship or break down the walls of a fort. A moment's reflection will satisfy the reader that the energy of a service projectile depends both upon its weight and its velocity; and it will readily be conceded that if the weight of a projectile be doubled or trebled, its capacity for work (or destruction), will be increased in the same ratio, other things being equal. That is, *the energy of a projectile is proportional to its weight.* It is not so evident in what proportion the energy of a projectile increases with its velocity. That it does increase with the velocity every base ball player knows; and undoubtedly most catchers have had, on many occasions, abundant reason to believe that the destructive effect of the ball upon the hands increases more rapidly than the simple velocity. And in this belief they are correct. If the velocity of the ball is doubled its energy is multiplied by four, and if the velocity is

Digitized by Google

trebled the energy is multiplied by nine. That is, *the energy of a projectile is proportional to the square of its velocity.*

As the energy of a moving projectile is proportional both to its weight and to the square of the velocity with which it is moving at any instant, it must be proportional to the product of these two; that is, the expression for the energy of a projectile must contain the product of its weight and the square of the velocity. It is usual to express the energy of a projectile in foot-tons; and the formula for computing the energy so expressed is the following:

$$E = 0.0000069407\, w v^2 \text{.....} (21).$$

The logarithm of the multipler is 4.84140 — 10, and Equation (21) may be written:

$$E = [4.84140 - 10]\, wv^2;$$

or, by logarithms,

$$\log E = 4.84140 - 10 + \log w + 2 \log v.$$

By Equation (21) we determine the weight, in tons, of a mass of matter, which, if falling freely from rest, through a distance of 1 foot, would acquire the same energy as the projectile in question has when moving with the given velocity. As all heavy bodies while falling 1 foot acquire the same velocity (about 8 f. s.), this method gives a ready means of comparing the energies of different moving projectiles. For example, the following table gives the muzzle energies of four projectiles, all differing in weight and having different muzzle velocities:

Kind of gun.	Weight of projectile.	Muzzle velocity.	Muzzle energy (foot-tons).
5-inch siege	45 lbs.	1830 f. s.	1,046
8-inch seacoast	300	1950	7,917
10-inch seacoast	575	1975	15,567
12-inch seacoast	1,000	2100	30,608

The last column of this table shows at a glance the relative muzzle energies of these four projectiles. Thus the 8-inch gun imparts an energy more than seven times that of the 5-inch gun; the 10-inch, double that of the 8-inch; and the 12-inch, double that of the 10-inch. It must not be inferred, however, that the striking effects of two projectiles are necessarily the same because they have the same striking energy. One of the projectiles, having a sharp point and made of hardened steel, might easily penetrate the side of an armored ship and cause its destruction; while the other, with a more blunt head and made of iron or soft steel, would be broken into fragments on impact and do no material damage.

The learner should verify the muzzle energies given in the above table, as exercises, using Equation (21) in its logarithmic form.

Example 13.—Compute the striking energy of the projectile of Example 12.

$$\begin{aligned} \text{Const. log} &= 4.84140 - 10 \\ \log w &= 1.30103 \\ 2 \log v &= \underline{6.00390} \\ \log E &= 2.14633 \quad \therefore \quad E = 140.06 \text{ foot-tons.} \end{aligned}$$

Thus the striking energy of this projectile after ranging 2,000 yards is 140 foot-tons. Its muzzle energy was 333 foot-tons; and the difference, 193 foot-tons, has been abstracted from it by the air in about six seconds. The learner will verify this statement.

Digitized by Google

Example 14.—Compute the striking energy of a service projectile fired from the 12-inch B. L. R. for a horizontal range of 2 miles. Also the time of flight.

The table on page 14 gives the muzzle velocity of this projectile, and we must compute the striking velocity at 2 miles, as in Example 12.

$$\begin{aligned} \log X &= 4.02366 \\ \log C &= 0.88740 \\ \log 1368.6 &= 3.13626 \\ S(V) &= 2024.8 \\ S(v) &= 3393.4 \quad \therefore \quad v = 1728.9 \text{ f. s.} \end{aligned}$$

$$\begin{aligned} \text{Const. log} &= 4.84140 - 10 \\ \log w &= 3.00000 \\ 2 \log v &= 6.47554 \\ \log E &= 4.31694 \quad \therefore \quad E = 20746 \text{ f. t.} \end{aligned}$$

$$\begin{aligned} T(v) &= 1.558 \\ T(V) &= 0.838 \\ \log 0.720 &= 9.85733 - 10 \\ \log C &= 0.88740 \\ \log T &= 0.74473 \quad \therefore \quad T = 5.56 \text{ sec.} \end{aligned}$$

In this case the air robs the projectile in the short space of five and one-half seconds of 9862 foot-tons of energy.

Example 15.—How many inches of steel plates could the projectile of Example 14 penetrate if at the end of its 2-mile range it struck the side of an armored ship normally?

$$\begin{aligned} \text{Const. log} &= 6.99066 - 10 \\ \tfrac{1}{2} \log 1000 &= 1.50000 \\ \log 1728.9 &= 3.23777 \qquad \text{(Equation (20).)} \\ & \quad 1.72843 \\ \tfrac{2}{4} \log 12 &= 0.809385 \\ & \quad 0.919045 \\ & \qquad\qquad 10 \\ & \quad 7 \,)\, 9.190450 \\ \log e &= 1.31292 \quad \therefore \quad e = 20.6 \text{ inches.} \end{aligned}$$

Example 16.—Compute the atmospheric pressure upon the head of a service projectile fired from the 16-inch B. L. R. (*a*) when it leaves the muzzle; (*b*) at the end of a 4000-yard range.

This example is an application of Equation (6), which may be expressed by logarithms as follows:

$$\log R_a = 4.64521 - 10 + 2 \log d + 2 \log v.$$

(*a*)

$$\begin{aligned} \text{Const. log} &= 4.64521 - 10 \\ 2 \log d &= 2.40824 \\ 2 \log v &= 6.59113 \\ \log R_a &= 3.64458 \quad \therefore \quad R_a = 4411 \text{ pounds.} \end{aligned}$$

Computation of striking velocity at 4000 yards.

(*b*)

$$\begin{aligned} \log X &= 4.07918 \\ \log C &= 1.01227 \\ \log 1166.6 &= 3.06691 \\ S(V) &= 2456.8 \\ S(v) &= 3623.4 \quad \therefore \quad v = 1673.3 \text{ f. s.} \end{aligned}$$

$$\begin{aligned} \text{Const. log} &= 4.64521 - 10 \\ 2 \log d &= 2.40824 \\ 2 \log v &= 6.44714 \\ \log R_a &= 3.50059 \quad \therefore \quad R_a = 3167 \text{ pounds.} \end{aligned}$$

Digitized by Google

Ballistic effects of atmospheric conditions.—We have already seen that the ballistic efficiency of projectiles may be increased by increasing their sectional density, by making them smoother and more pointed, and by centering them better in the gun. All these qualities relate to the projectiles themselves, and when these latter have been determined upon the ballistic coefficient C becomes a constant for each projectile, and may be tabulated for ready use, as has been done on page 14. There is still another factor modifying the ballistic efficiency of a projectile, and independent of it, which, for accurate shooting, must be taken into account, namely, the varying density of the air. It needs no argument to convince the learner that the denser (heavier) the air is the greater the resistance it will offer to the motion of a projectile; and, conversely, the less the density the less the resistance offered. And he will probably be ready to admit that the resistance varies directly as the density of the air; that is, if the density of the air could be doubled its resistance to the motion of a projectile would be doubled, and the ballistic efficiency of the projectile halved. And if the density of the air could be halved the ballistic efficiency of a projectile would be doubled, and so on. Now the density of the air changes both with the barometric pressure and with the temperature; so that, as is well known to our gunners, a reading of the barometer and of the thermometer are both taken at target practice, and these data are required in order to get the atmospheric factor of efficiency, (F_a), for the day. These factors are given in Table III. With the construction of this table (as with the construction of Tables I and II) the learner need not concern himself; but it is essential that he should be able to use the table; that is, to take from it the atmospheric factor, F_a, for any given readings of the thermometer and barometer. The temperatures are given in the first and sixth columns for every degree (Fahrenheit) from 0° to 100°, while the barometric pressures for every inch of mercury from 28 inches to 31 inches inclusive, are found in the upper horizontal column. The atmospheric factor for any given tabular temperature and pressure will be found in the given pressure column, and in the horizontal line through the given temperature. Thus the atmospheric factor for 60° and 30 inches is unity; that is, for these particular conditions the use of the atmospheric factor is not required. The same is true for 26° and 28 inches, for 43° and 29 inches, and for 77° and 31 inches. But for 80° and 30 inches we have $F_a = 1.039$; that is, for this temperature and pressure the air is less dense than the standard density upon which Tables I and II are based, and consequently the ballistic efficiency of any projectile moving in this air is increased and in the same ratio as the density decreases. It follows, then, in the case supposed, that instead of using C as a factor (or divisor) in our ballistic formulas we must use $1.039\,C$. On the other hand, if the temperature of the air be 28° and barometric pressure 31 inches, we shall have $F_a = 0.907$; and instead of C, should use $0.907\,C$. And, in general, whenever the atmospheric factor, F_a, is not unity we must employ $F_a\,C$ instead of C in all ballistic formulas. We will designate C, multiplied by the atmospheric factor, by C_a—which means C corrected for atmospheric conditions. Thus

$$C_a = F_a C.$$

As an illustration take the data of Example 12, which we will restate as follows:

Example 17.—Compute the striking velocity and time of flight of a service projectile fired from the 3.6-inch field gun for a range of 2000 yards when the thermometer registers 90° F. and the barometer 30 inches.

Digitized by Google

By reference to Table III we find $F_a = 1.059$. The calculations are arranged as follows:

$$\log C = 0.23418$$
$$\log F_a = \underline{0.02489}$$
$$\log C_a = \overline{0.25907}$$
$$\log X = \underline{3.77815}$$
$$\log 3304.3 = 3.51908$$
$$S(V) = \underline{4162.2}$$
$$S(v) = 7466.5 \quad \therefore \quad v = 1020.5.$$
$$T(v) = 4.718$$
$$T(V) = \underline{2.027}$$
$$\log \overline{2.691} = 0.42991$$
$$\log C_a = \underline{0.25907}$$
$$\log T = \overline{0.68898} \quad \therefore \quad T = 4.89 \text{ sec.}$$

In Example 12 the temperature of the air was supposed to be 60° F. and the barometer 30 inches. This is called the normal atmosphere, and for this, as we have seen, $F_a = 1$, and $C_a = C$. It follows from Example 17 that for this particular gun and projectile an increase of temperature of 30° above the normal gives for a range of 2000 yards an increase of striking velocity of 16 f. s. and a diminution in the time of flight of 0.06 seconds.

Table III gives the atmospheric factor for every degree of the thermometer, which is amply sufficient for all practical purposes. The barometric reading is given in inches and thousandths of an inch, and for this an interpolation is generally required in taking out F_a from the table. To do this take out the tabular number for the *whole* number of inches and subtract from it $\frac{1}{30}$ of the fractional part of an inch. The remainder will be the required value of F_a. For example, suppose the temperature of the air to be 80° and height of barometer 30.269 inches; what is the value of F_a? We have, according to the rule,

$$F_a = 1.047 - \frac{1}{30} \times 0.269 = 1.047 - 0.009 = 1.038.$$

Example 18.—Compute the striking velocity and time of flight for each of our B. L. seacoast guns for a range of 3000 yards (*a*) when the air is normal; (*b*) when the thermometer registers 32° and the barometer 30.192 inches.

ANSWERS.

	a.		*b.*	
8-inch	1525.5 f. s.	5.23 sec.	1501.3 f. s.	5.27 sec.
10-inch	1616.7	5.05	1595.8	5.08
12-inch	1779.3	4.66	1760.2	4.69
16-inch	1744.1	4.86	1730.1	4.88

Example 19.—Compute the striking velocity and time of flight of the Springfield rifle bullet for each of the following ranges: 100, 200, 400, 800, and 1000 yards. Air normal.

Data: $V = 1275$ f. s., $d = 0.45$ in., $w = 500$ grains or $\frac{1}{14}$ of a pound, and coefficient of reduction = 1.

First compute the logarithm of C as follows:

$$C = \frac{w}{d^2} = \frac{1}{14} \div \left(\frac{45}{100}\right)^2 = \frac{1}{14} \times \frac{10000}{2025} = \frac{200}{567}$$
$$\log 200 = 2.30103 = 12.30103 - 10$$
$$\log 567 = \underline{2.75358}$$
$$\log C = 9.54745 - 10$$

Digitized by Google

ANSWERS.

X.	v.	T.
100 yds	1140.5 f. s.	0.25 sec.
200 yds	1040.8	0.53
400 yds	916.0	1.14
800 yds	741.1	2.61
1,000 yds	670.4	3.46

Example 20.—What must be the muzzle velocity of a 12-inch service projectile in order to penetrate 22 inches of steel plates at 2500 yards from the gun?

We must first compute by de Marre's penetration formula the striking velocity which this projectile must have in order to penetrate 22 inches of steel, and then the muzzle velocity by Equation (9). If we multiply both members of Equation (21) by $\frac{7}{10}$ it becomes

$$\frac{7}{10}e = 6.99066 - 10 + \frac{1}{2}\log w + \log v - \frac{3}{4}\log d;$$

then by simple algebraic transpositions we have

$$\log v = 10 - 6.99066 + \frac{3}{4}\log d + \frac{7}{10}\log e - \frac{1}{2}\log w;$$

or, by subtracting 6.99066 from 10,

$$\log v = 3.00934 + \frac{3}{4}\log d + \frac{7}{10}\log e - \frac{1}{2}\log w \quad \ldots\ldots (22).$$

The numerical work is as follows:

$$\begin{aligned}
\text{Const. } \log &= 3.00934 \\
\tfrac{3}{4}\log d &= 0.809385 \\
\tfrac{7}{10}\log e &= \underline{0.939694} \\
&\quad 4.75842 \\
\tfrac{1}{2}\log w &= \underline{1.50000} \\
\log v &= 3.25842 \quad \therefore \quad v = 1813.1 \text{ f. s.} \\
\log X &= 3.87506 \\
\log C &= \underline{0.88740} \\
\log 972.0 &= 2.98766 \\
S(v) &= \underline{3058.8} \\
S(V) &= 2086.8 \quad \therefore \quad V = 2081.6 \text{ f. s.}
\end{aligned}$$

Therefore the muzzle velocity must be 2081.6 f. s.

Example 21.—Compute the muzzle velocity of a service projectile fired from the 10-inch B. L. R. which is able to penetrate 18.5 inches of steel at 1000 yards from the gun.

ANSWER.

$v = 1847.3$ f. s.
$V = 1974.8$.

Example 22.—Compute the respective ranges for which the B. L. seacoast guns lose 15 per cent of their muzzle velocities.

ANSWERS.

8-inch	1986 yds.
10-inch	2436
12-inch	2942
16-inch	3922

Digitized by Google

CHAPTER II.

Angle of elevation.—All gunners who have taken part in actual target practice know that there is a close relation between the elevation of the muzzle of the gun (angle of elevation) and the distance the projectile will go before striking. Their experience teaches them that if the projectile strikes short of the target the elevation must be increased; or, if the shot goes over, the elevation must be diminished, other things being equal. This necessary relation between elevation and range is naturally recognized by the Indian when he shoots his arrows, by the boy in throwing stones, and by the base ball player, each of whom gives to his projectile, without thought, the proper initial direction or elevation due to the distance of the object he desires to hit or reach.

Angle of departure.—Jump.—It has been shown by a great many experiments that when a loaded gun is fired at any ordinary angle of elevation the muzzle "jumps" before the projectile leaves the bore in such a way that the angle with which the projectile starts on its flight is always greater than the angle of elevation which had been given to the gun. This "projectile" angle is called the *angle of departure*, and the amount by which it exceeds the angle of elevation of the gun is called the *jump*. It is evident that the range of a projectile depends upon its angle of departure, and we shall therefore use this term instead of angle of elevation in all that follows. It was not necessary to make this distinction between these two angles in Chapter I, since, as we stated at the outset, the angles of elevation, or departure, would be taken so small that the curvature of the trajectory would have no appreciable effect upon either the range or time of flight, which were the only ballistic elements considered in that chapter.

The jump varies with the gun, mounting, platform, and angle of elevation, and must be determined by experiment in each case. When known it must be subtracted from the angle of departure found in the range table to give the angle of elevation required for laying the gun.

Formula for small angles of departure.—We have given a formula in Chapter I for the horizontal range in terms of the muzzle and striking velocities; or, rather, in terms of the space functions of those velocities, namely:

$$X = C\{S(v) - S(V)\}$$

and a similar formula for the time of flight in terms of time functions. We shall now give a formula, not quite as simple in form as the above, but of the same nature, for the angle of departure, which will be expressed in terms of certain other functions of the velocities. This formula is the following:

$$\sin 2a = C\left\{\frac{A(v)-A(V)}{S(v)-S(V)} - I(V)\right\} \quad \text{.....(23).}$$

In this formula the symbols $A(v)$ and $A(V)$ are called "altitude functions", and their values for different velocities are given in the fourth columns of Tables I and II; while alongside in the fifth columns are given the differences (d_1) between each two consecutive functional values to be used with the interpolation formulas (11) and (12), already explained. The symbol $I(V)$ is called the "inclination function", and its values and differences are given in the sixth and seventh columns, respectively, of the ballistic tables. It will be observed that the inclination function of the muzzle velocity only enters into Equation (23); the inclination function of the striking velocity will appear in another formula further on.

Equation (23) may be expressed in words as follows: Divide the difference of the altitude functions of the striking and muzzle velocities by the difference of their space functions, subtract from the quotient the inclination function of the muzzle velocity, and multiply the

Digitized by Google

remainder by the ballistic coefficient. The product is the sine of twice the angle of departure (this latter represented by a). It will be seen that this equation (or rule) does not give the angle of departure (a) directly, but a certain function of this angle called its sine, just as Equation (8) does not give the striking velocity, but the space function of this velocity. But just as the space functions of velocities have been computed and tabulated, so have the sine functions of angles been tabulated; and we may say that an angle is given or known when its sine is known, since we can take the angle directly from the table of sines. This the learner is supposed to know how to do without further instruction.

We will now give some examples of the computation of angles of departure, and for this purpose shall largely use the data already given in Chapter I.

Example 23.—The 8-inch converted rifle, loaded with the service charge and projectile, is so elevated that the velocity at the end of the horizontal range is reduced from 1400 f. s., its initial value, to 1300 f. s. What is the angle of departure?

Taking from Table I the proper functions of the given velocities, the numerical operations may be indicated as follows:

$$\sin 2a = 2.8125 \left\{ \frac{213.72 - 163.96}{5399.2 - 4878.6} - 0.08661 \right\} = 2.8125 \left\{ \frac{49.76}{520.6} - 0.08661 \right\} = 2.8125\ (0.09558 - 0.08661)$$
$$= 2.8125 \times 0.00897 = 0.02523.$$

Turning now to a table of natural sines, we find that the angle whose sine is 0.02523 is 1° 26′. Therefore

$$2a = 1^\circ\ 26'$$
$$\text{and} \quad a = 0^\circ\ 43'$$

That is, the angle of departure of the projectile in order that its striking velocity may be reduced from 1400 f. s. to 1300 f. s., is forty-three minutes of arc. The corresponding horizontal range is 488 yards, and the time of flight 1.09 seconds. (See Example 1). It will be readily seen that if the angle of departure were increased beyond 43′ the horizontal range and time of flight would also be increased; and consequently, the striking velocity *decreased*, since the projectile constantly loses velocity while moving through the air in consequence of the continual resistance which the latter imposes. On the other hand, if the angle of departure were diminished, the horizontal range and time of flight would also be diminished and the projectile would lose less of its velocity than before; in other words its striking velocity would be greater. All these facts, which seem evident without the aid of mathematical reasoning, are embodied in Equation (23), and are the basis upon which it was deduced.

Remarks.—In dividing the difference of the altitude functions by the difference of the space functions, carry the quotient to five places of decimals to correspond with the number of decimals in the tabular inclination functions.

Take out the angle corresponding to the computed sine to the nearest even minute, so that it can be halved without a remainder.

The solution of Example 23 by logarithms is as follows:

$$\begin{aligned}
A(v) &= 213.72 \\
A(V) &= 163.96 \\
\log\ \overline{49.76} &= 11.69688 - 10 \\
S(v) &= 5399.2 \\
S(V) &= 4878.6 \\
\log\ \overline{520.6} &= \underline{2.71650} \\
\log 0.09558 &= \overline{8.98038} - 10 \\
I(V) &= 0.08661 \\
\log\ \overline{0.00897} &= 7.95279 - 10 \\
\log C &= \underline{0.44909} \\
\log \sin 2a &= \overline{8.40188} - 10 \quad \therefore \quad 2a = 1^\circ\ 26' \\
& \qquad\qquad\qquad\qquad\quad a = 0\ 43
\end{aligned}$$

Digitized by Google

In the logarithmic work that follows we shall omit the "— 10" at the right of a logarithm of a decimal fraction as being unneccessary. The learner will of course understand that it belongs there, and if any confusion is likely to arise in his mind by its omission he can replace it at any time; but if the computer will allow it to do so this "— 10" will take care of itself in the great majority of cases without any thought on his part.

Equation (23) is usually combined with Equation (4) for reasons which will be apparent as we proceed. Thus dividing both members of Equation (4) by C it becomes:

$$\frac{X}{C} = S(v) - S(V);$$

we may therefore write in the second member of Equation (23), for $S(v) - S(V)$, its equal $\frac{X}{C}$, and it becomes

$$\sin 2a = C \left\{ \frac{A(v) - A(V)}{\frac{X}{C}} - I(V) \right\}.$$

This last equation will present a neater appearance if we employ a single letter instead of $\frac{X}{C}$. Let us then make

$$\frac{X}{C} = z = S(v) - S(V) \quad \text{.....(24),}$$

and the expression for sin. $2a$ becomes

$$\sin 2a = C \left\{ \frac{A(v) - A(V)}{z} - I(V) \right\} \quad \text{.....(25).}$$

Example 24.—Compute the angle of departure for the 3.2-inch field gun loaded with the service charge and projectile, for a range of 1500 yards.

This is the usual statement of examples requiring the computation of angles of departure; and, as will be seen, the striking velocity is not given—only the data upon which it depends. We must first compute the striking velocity by Equation (8), and then the angle of departure by Equation (25). The entire work is given below, and the learner is recommended to use it as a model in subsequent examples. The interpolations should be done on a separate piece of paper for the sake of neatness.

(Equation (8).)

$$\begin{aligned} \log X &= 3.65321 \\ \log C &= \underline{0.16579} \\ \log 3072.0 &= 3.48742 = \log z. \\ S(V) &= \underline{3574.5} \\ S(v) &= 6646.5 \quad \therefore \quad v = 1105.5 \end{aligned}$$

(Equation (25).)

$$\begin{aligned} A(v) &= 377.94 \\ A(V) &= \underline{75.77} \\ \log 302.17 &= 2.48025 \\ \log z &= \underline{3.48742} \\ \log 0.09836 &= 8.99283 \\ I(V) &= \underline{0.05086} \\ \log 0.04750 &= 8.67669 \\ \log C &= \underline{0.16579} \\ \log \sin 2a &= 8.84248 \quad \therefore \quad 2a = 4^\circ\ 00' \\ & \qquad\qquad\qquad\quad a = 2^\circ\ 00' \end{aligned}$$

Digitized by Google

Example 25.—Compute the angles of departure for the 8-inch converted rifle for the various ranges given in Example 2. Use the striking velocities already computed.

ANSWERS.

Range, in yards.	Angle of departure.
1200	1° 53′
1400	2 14
1600	2 37
1800	3 00
2000	3 25

Example 26.—With a charge of 20 pounds of cannon powder the 10-inch S. B. gun ($d = 9.87$ inches) fires shot and shell as follows: Shot weighing 128 pounds with a muzzle velocity of 1358 f. s. Shell weighing 107 pounds with a muzzle velocity of 1493 f. s. Compute the angle of departure in each case for a range of 1500 yards.

(Solid shot.)

$\log X = 3.65321$
$\log C = 0.11857$
$\log 3425 = 3.53464 = \log z$
$S(V) = 1901$
$S(v) = 5326 \quad \therefore \quad v = 803.5$ f. s.

$A(v) = 516.93$
$A(V) = 38.37$
$\log 478.56 = 2.67994$
$\log z = 3.53464$
$\log 0.13974 = 9.14530$
$I(V) = 0.04617$
$\log 0.09357 = 8.97113$
$\log C = 0.11857$
$\log \sin 2a = 9.08970 \quad \therefore \quad 2a = 7° 04′$
$a = 3\ 32$

(Shell.)

$\log X = 3.65321$
$\log C = 0.04075$
$\log 4097 = 3.61246 = \log z$
$S(V) = 1436$
$S(v) = 5533 \quad \therefore \quad v = 785.8$ f. s.

$A(v) = 575.88$
$A(V) = 20.33$
$\log 555.55 = 2.74474$
$\log z = 3.61246$
$\log 0.13561 = 9.13228$
$I(V) = 0.03138$
$\log 0.10423 = 9.01799$
$\log C = 0.04075$
$\log \sin 2a = 9.05874 \quad \therefore \quad 2a = 6° 34′$
$a = 3\ 17$

These results show that the angle of departure of the lighter projectile (shell) is less than that of the heavier shot for a range of 1500 yards. This is of course due to the greater muzzle velocity of the former. For a range of about 2300 yards the two angles of departure

Digitized by Google

are the same; and for ranges greater than that the angle of departure of the shot will be less than for the shell.

Example 27.—Compute the angles of departure for the respective ranges of Example 22. Also times of flight.

ANSWERS.

8-inch gun...	$a = 1° 37'$	$T = 8.32$ sec.
10-inch gun...	1 56	4.02
12-inch gun...	2 04	4.56
16-inch gun...	3 07	6.47

Trajectory in a vacuum.—If there were no air or other obstruction to impede the free motion of a projectile it would describe a curve called a parabola, whose general form is represented in Fig. 1 by the curved line ABC. This curve shows the trajectory which any projectile whatever—light or heavy, rough or smooth, regular or irregular in form—would describe in a vacuum, if it started from A with a velocity of 751 f. s., and an angle of departure A′AC of 30°. The horizontal range AC is 15188 feet and the greatest height of the trajectory (at B) is 2192 feet. If we drop a perpendicular BD from the summit B the trajectory is said to be *symmetrical* with respect to this line; that is, if we imagine the descending branch BC to revolve over toward the left about BD (as in folding the paper through this line), the point C will fall upon A, and the descending branch BC will fall upon the ascending branch AB, coinciding exactly throughout. Moreover the tangent (or direction) of the curve at the point of fall C (CC′) will fall exactly upon AA′, the tangent at the point of departure A; that is, the angle of fall C′CA is equal to the angle of departure A′AC. Finally, the velocity of the projectile at C is the same as at A, and greater than at any intermediate point. Beginning at A the velocity continually decreases to B, where it is least, and then increases from B to C at the same rate, but in a reverse order, as it decreased from A to B; so that at any two equal distances to the right and left of B the velocities are the same. It will thus be seen that there is a symmetry of velocity, as well as of form in the two branches of a trajectory in a vacuum.

These results all follow from the fact that in a vacuum there is but one force acting upon the projectile after its departure from A, namely, the force of gravitation, which manifests itself in a constant downward pull, and which, in the ascending branch destroys the upward motion given to the projectile at the start, and restores this motion, unimpaired, in the descending branch. That is, this single constant force (or pull) reverses in the descending branch all that it did to the projectile in the ascending branch.

Trajectory in air.— Now let us look at the curve AEF, which is an actual trajectory described in air. The ballistic coefficient C (which plays no part in determining the trajectory in a vacuum) must, on account of the resistance of the air, be now introduced. The curve AEF is the trajectory which an oblong projectile 6.27 inches in diameter and weighing 70 pounds ($C = 1.78$) would describe in air if it started from A with a velocity of 751 f. s. and angle of departure of 30°; that is, with the same initial conditions which, in a vacuum, would cause it to describe the parabolic trajectory ABC. The horizontal range AF is now but 11396 feet, and greatest altitude GE 1873 feet; that is, the resistance of the air has in this particular case reduced the horizontal range in a vacuum by 3792 feet, or 25 per cent, and the maximum altitude by 319 feet, or 15 per cent. If we drop a perpendicular EG from the highest point of the trajectory E, it will not divide the horizontal range AF into two equal parts (or segments) as we found to be the case in a vacuum; but the near segment AG will always be greater than the far segment GF. In the example under consideration AG is 6062

Digitized by Google

feet, and GF 5334 feet. Further, if we imagine the descending branch EF to be revolved over to the left about the perpendicular EG, we shall find that not only will F fall short of A, but that every point of the descending branch will fall below the ascending branch; that is, the descending branch is steeper than the ascending branch, and therefore the angle of fall F′FA is greater than the angle of departure A′AF, and this necessitates an expression for computing the former as well as for the latter. It will be seen from all this that the symmetry of form which characterizes the parabolic trajectory in a vacuum is wanting in the actual trajectory in air. The striking velocity, also, is always less than the initial velocity, and is not the same at two points equally distant to the right and left of E, as in the parabolic trajectory.

The reason for this lack of symmetry is not far to seek. The projectile moving in air is acted upon by the same constant downward pull of gravitation as the supposed projectile moving in a vacuum; but it also has, in addition to this, to overcome the resistance of the air, which latter may be regarded as a variable push against the head of the projectile in the direction of its axis, continually impeding its motion and reducing its velocity, and, therefore, its range and altitude. The force of gravitation, as we have seen, restores to the projectile in the descending branch all the motion it took from it in the ascending branch. But not so with the resistance of the air; it constantly robs the projectile of motion, but never restores any of it. If the sectional density of the projectile be increased, the initial velocity and angle of departure remaining the same, the horizontal range and greatest altitude will also be increased; but no possible increase in the sectional density can bring F to C or E to B.

Angle of fall.—The formula for angle of fall (which angle we will designate by b) is similar in form to that for the angle of departure already given. For small angles it is

$$\sin 2b = C\left\{ I(v) - \frac{A(v) - A(V)}{S(v) - S(V)} \right\} \quad \text{.....(26).}$$

In this formula there are no new functions, the only difference between this and Equation (23) being that the inclination function of striking velocity takes the place of the same function of muzzle velocity, and the terms within the braces are reversed.

Using z in place of $S(v) - S(V)$ Equation (26) becomes

$$\sin 2b = C\left\{ I(v) - \frac{A(v) - A(V)}{z} \right\} \quad \text{.....(27).}$$

Equation (26) expressed in words is as follows:

Divide the difference of the altitude functions of the striking and muzzle velocities by the difference of their space functions, subtract the quotient from the inclination function of the striking velocity, and multiply the remainder by the ballistic coefficient. The product is the sine of twice the angle of fall.

Example 28.—The 8-inch converted rifle, loaded with the service charge and projectile, is so elevated that the velocity at the end of the horizontal range is reduced from 1400 f. s., its initial value, to 1300 f. s. What is the angle of fall?

Taking from Table I the proper functions of the given velocities, we may express the answer as follows:

$$\sin 2b = 2.8125\left\{ 0.10503 - \frac{213.72 - 163.96}{5399.2 - 4878.6} \right\} = 2.8125\left\{ 0.10503 - \frac{49.76}{520.6} \right\}.$$

$$= 2.8125\ (0.10503 - 0.09558) = 2.8125 \times 0.00945 = 0.02658$$

Therefore, from the table of natural sines, we find

$$2b = 1^\circ\ 32'$$

and $$b = 0^\circ\ 46'$$

Digitized by Google

The solution of Example 28 by logarithms is as follows:

$$A(v) = 213.72$$
$$A(V) = 163.96$$
$$\log 49.76 = 1.69688$$
$$S(v) = 5399.2$$
$$S(V) = 4878.6$$
$$\log 520.6 = 2.71650$$
$$\log 0.09558 = \overline{8.98038}$$
$$I(v) = 0.10503$$
$$\log 0.00945 = 7.97543$$
$$\log C = \overline{0.44909}$$
$$\log \sin 2b = \overline{8.42452} \quad \therefore \quad 2b = 1^\circ\ 32'$$
$$b = 0\ 46$$

Example 29.—Compute the angle of fall for a service projectile fired from the 3.2-inch field gun, with service charge, for a range of 1500 yards.

We must first compute the striking velocity by Equation (8) and then the angle of fall by Equation (27). By referring to the solution of Example 24 (of which the present example is a continuation) it will be seen that the greater part of the labor required to compute the angle of fall was there performed to determine the angle of departure. That is, the computations of the striking velocity and of the term

$$\frac{A(v) - A(V)}{z}$$

are common to both examples, and need not be repeated. We have from the solution of Example 24

$$v = 1105.5 \text{ f. s.},$$

and $$\frac{A(v) - A(V)}{z} = 0.09836$$

also from Table I,

$$I(v) = 0.16136$$
$$\log 0.06300 = 8.79934$$
$$\log C = \overline{0.16579}$$
$$\log \sin 2b = \overline{8.96513} \quad \therefore \quad 2b = 5^\circ\ 18'$$
$$b = 2\ 39$$

We see from this solution that the additional labor of computing the angle of fall after the angle of departure has been determined, is very slight.

Example 30.—Compute the angles of fall for the respective ranges of Example 22.

ANSWERS.

8-inch gun	$b = 1^\circ\ 48'$
10-inch gun	2 09
12-inch gun	2 18
16-inch gun	3 28

Velocity of projectile at summit of trajectory for small angles of departure.—In each of Equations (23) and (26) we find the ratio

$$\frac{A(v) - A(V)}{S(v) - S(V)};$$

that is, the difference of the altitude functions of the striking and muzzle velocities divided by the difference of the space functions of the same velocities. It can be shown mathematically that, for small angles of departure this ratio is equal to the inclination function of the

Digitized by Google

summit velocity. We thus have for the three most characteristic velocities of a trajectory, namely, muzzle velocity (V), summit velocity (v_0) and striking velocity (v), the relation

$$I(v_0) = \frac{A(v) - A(V)}{S(v) - S(V)} \text{------(28).}$$

The symbol v_0, used to designate summit velocity, is read "v-sub zero," meaning the velocity of the projectile at that part of its trajectory which is parallel to the horizontal range, and therefore has no (or zero) inclination to the latter. Following out the same idea we might represent muzzle velocity by v_a and striking velocity by v_b; but the symbols already employed to designate these velocities are simpler, and will be retained.

It will be seen that in determining either the angle of departure or the angle of fall, we must first compute $I(v_0)$, so that the only additional labor to find the summit velocity is the taking it from Table I or Table II.

We may express the formulas for the angle of departure (Equation (23)) and the angle of fall (Equation (26)) in more concise and elegant form, by means of the inclination function of the summit velocity. Thus Equation (23) becomes by simple substitution

$$\sin 2a = C\{I(v_0) - I(V)\} \text{------(29);}$$

that is, the sine of twice the angle of departure is equal to the difference of the inclination functions of the summit and muzzle velocities multiplied by the ballistic coefficient.

By the same substitution Equation (26) becomes

$$\sin 2b = C\{I(v) - I(v_0)\} \text{------(30);}$$

that is, the sine of twice the angle of fall is equal to the difference of the inclination functions of the striking and summit velocities multiplied by the ballistic coefficient.

The learner will of course understand that Equations (29) and (30) differ from Equations (23) and (26) in form only. Not only the same amount of work is required, but identically the same work whether we use one set of equations or the other, since $I(v_0)$ must be computed by Equation (28) in case we use Equations (29) and (30). These latter equations having the same form as Equations (4) and (5), for the range and time of flight, respectively, are perhaps more easily remembered than those first given.

Example 31.—What are the summit velocities of the projectiles of Examples 23, 24, and 26?

The value of $I(v_0)$ has already been computed for each of these projectiles, and from Tables I and II we take out the required velocities.

ANSWERS.

8-inch gun	v_0 = 1348.7 f. s.
3.2-inch gun	1333.8
10-inch gun. (shot)	976.8
10-inch gun. (shell)	985.5

Example 32.—What are the summit velocities of the projectiles of Example 30?

ANSWERS.

8-inch gun	v_0 = 1793.6 f. s.
10-inch gun	1816.7
12-inch gun	1931.6
16-inch gun	1816.7

Digitized by Google

Horizontal distance from muzzle of gun to summit of trajectory.—By horizontal distance from muzzle of gun to summit of trajectory is meant the distance from the muzzle, measured on the line AC or AF, representing the horizontal range, to the point directly beneath the projectile when at its greatest height, as AD for the trajectory ABC, or AG for the trajectory AEF, Let us call this horizontal distance x_0 to correspond with the notation already adopted for the summit velocity. The learner has already been told that for a trajectory in a vacuum x_0 in one-half X, that is, AD = DC; but for an actual trajectory x_0 is always greater than one-half X, or, what is the same thing, AG in the figure is always greater than GF. The expression for x_0 is

$$x_0 = C\{S(v_0) - S(V)\} \quad \text{.....(31).}$$

Example 33.—Compute the horizontal distance to the summits of the trajectories of Examples 23, 24, and 26.

As the muzzle velocities for these guns are known and the summit velocities were computed in Example 31, we have only to take out the proper space functions from the tables and substitute them in Equation (31). The space functions of the muzzle velocities have already been taken out. For the 8-inch converted rifle the work by logarithms is as follows:

$$\begin{aligned} S(v_0) &= 5141.4 \\ S(V) &= \underline{4878.6} \\ \log 262.8 &= 2.41962 \\ \log C &= \underline{0.44909} \\ \log x_0 &= \overline{2.86871} \quad \therefore\ x_0 = 739 \text{ ft.} \end{aligned}$$

We have seen (Example 1), that the horizontal range of this projectile is 1464 feet. The perpendicular from the summit divides the horizontal range into two segments, AG and GF, which we have called the near and far segment, respectively. We have found the length of the near segment in this example to be 739 feet; the length of the far segment will then be 1464 − 739 = 725 feet.

The answers for the other trajectories of Example 33 are as follows:

	Near Segment.	Far Segment.
3.2-inch gun	2410 ft.	2090 ft.
10-inch (shot)	2435.	2065.
10-inch (shell)	2478.	2022.

Highest flight of trajectory.—The highest flight of a trajectory is measured by the perpendicular EG dropped from the summit to the horizontal line AF. The perpendicular EG is called the maximum ordinate, and will be represented by the symbol y_0. The formula for computing the maximum ordinate is, for small angles of elevation,

$$y_0 = \frac{C^2}{2}\left\{\frac{x_0}{C} I(v_0) + A(V) - A(v_0)\right\} \quad \text{.....(32).}$$

In using this formula it will be necessary to know three things, namely, the horizontal range, the muzzle velocity, and the ballistic coefficient. With these given we proceed as follows: We first compute the striking velocity v by Equation (8), which, as will be seen, requires in the second member just the data mentioned above. Next we compute v_0 by Equation (28) and then x_0 by Equation (31). We now have all the data required in Equation (32), and the computation of y_0 is readily effected.

Example 34.—Compute the maximum ordinate for the 1000-yard trajectory of the 8-inch B. L. R. In this example we have given $V = 1950$ f. s.; $X = 3000$ ft.; and $\log C = 0.71670$.

Digitized by Google

1. Compute v. (Equation. (8).)

$$\log X = 3.47712$$
$$\log C = \underline{0.71670}$$
$$\log 576.0 = 2.76042 = \log z.$$
$$S(V) = \underline{2546.4}$$
$$S(v) = 3122.4 \quad \therefore \quad v = 1796.8 \text{ f. s.}$$

2. Compute v_0. (Equation. (28).)

$$A(v) = 54.99$$
$$A(V) = \underline{34.35}$$
$$\log 20.64 = 1.31471$$
$$\log z = \underline{2.76042}$$
$$\log 0.03583 = 8.55429 = \log I(v_0) \quad \therefore \quad v_0 = 1870.4 \text{ f. s.}$$

3. Compute x_0 and y_0. (Equations (31) and (32).)

$$S(v_0) = 2839.7$$
$$S(V) = \underline{2546.4}$$
$$\log 293.3 = 2.46731$$
$$\log C = \underline{0.71670}$$
$$\log x_0 = 3.18401 \quad \therefore \quad x_0 = 1528 \text{ ft.}$$
$$\log I(v_0) = 8.55429$$
$$\text{a. c. } \log C = \underline{9.28330}$$
$$\log 10.51 = 1.02160$$
$$A(V) = \underline{34.35}$$
$$44.86$$
$$A(v_0) = \underline{44.11}$$
$$\log 0.75 = 9.87506$$
$$\log C^2 = 1.43340$$
$$\text{a. c. } \log 2 = \underline{9.69897}$$
$$\log y_0 = 1.00743 \quad \therefore \quad y_0 = 10.17 \text{ ft.}$$

Example 35.—Compute the coördinates of the summit of the 1000-yard trajectory of the 8-inch converted rifle. $V = 1414$ f. s.

$$\log X = 3.47712$$
$$\log C = \underline{0.44909}$$
$$\log 1066.7 = 3.02803 = \log z.$$
$$S(V) = \underline{4808.6}$$
$$S(v) = 5875.3 \quad \therefore \quad v = 1218.0 \text{ f. s.}$$
$$A(v) = 268.24$$
$$A(V) = \underline{157.97}$$
$$\log 110.27 = 2.04245$$
$$\log. z = \underline{3.02803}$$
$$\log 0.10338 = 9.01442 = \log I(v_0) \quad \therefore \quad v_0 = 1308 \text{ f. s.}$$
$$S(v_0) = 5355.9$$
$$S(V) = \underline{4808.6}$$
$$\log 547.3 = 2.73822$$
$$\log C = \underline{0.44909}$$
$$\log x_0 = 3.18731 \quad \therefore \quad x_0 = 1539 \text{ ft.}$$
$$\log I(v_0) = 9.01442$$
$$\text{a. c. } \log C = \underline{9.55091}$$
$$\log 56.58 = 1.75264$$
$$A(V) = \underline{157.97}$$
$$214.55$$
$$A(v_0) = \underline{209.22}$$
$$\log 5.33 = 0.72672$$
$$\log C^2 = 0.89818$$
$$\text{a. c. } \log 2 = 9.69897$$
$$\log y_0 = 1.32387 \quad \therefore \quad y_0 = 21.08 \text{ ft.}$$

Digitized by Google

Example 36.—Compute the coördinates of the summit of the 1000-yard trajectory of the Springfield rifle. For data see Example 19.

$$\log X = 3.47712$$
$$\log C = \underline{9.54745}$$
$$\log 8505.0 = 3.92967 = \log s$$
$$S(V) = \underline{5538.0}$$
$$S(v) = 14043.0 \quad \therefore \quad v = 670.45 \text{ f. s.}$$

$$A(v) = 3745.45$$
$$A(V) = \underline{228.67}$$
$$\log 3516.78 = 3.54614$$
$$\log. s = \underline{3.92967}$$
$$\log 0.41350 = 9.61647 = \log I(v_0) \quad \therefore \quad v_0 = 844.08 \text{ f. s.}$$

$$S(v_0) = 10178.5$$
$$S(V) = \underline{5538.0}$$
$$\log 4640.5 = 3.66657$$
$$\log C = \underline{9.54745}$$
$$\log x_0 = 3.21402 \quad \therefore \quad x_0 = 1637 \text{ ft.}$$

$$\log I(v_0) = 9.61647$$
$$\text{a. c. } \log C = \underline{0.45255}$$
$$\log 1918.80 = 3.28304$$
$$A(V) = \underline{228.67}$$
$$2147.47$$
$$A(v_0) = \underline{1354.88}$$
$$\log 792.59 = 2.89904$$
$$\log C^2 = 9.09490$$
$$\text{a. c. } \log 2 = \underline{9.69897}$$
$$\log y_0 = 1.69291 \quad \therefore \quad y_0 = 49.31 \text{ ft.}$$

Example 37.—Compute the angles of departure and angles of fall of the trajectories of the three preceding examples.

Solution for the 8-inch B. L. R., employing Equations (29) and (30), and remembering that $I(v_0)$ has already been computed:

$$I(v_0) = 0.03583$$
$$I(V) = \underline{0.03066}$$
$$\log 0.00517 = 7.71349$$
$$\log C = \underline{0.71670}$$
$$\log \sin 2a = \overline{8.43019} \quad \therefore \quad 2a = 1^\circ\ 32'$$
$$a = 0\ 46$$

$$I(v) = 0.04126$$
$$I(v_0) = \underline{0.03583}$$
$$\log 0.00543 = 7.73480$$
$$\log C = \underline{0.71670}$$
$$\log \sin 2b = \overline{8.45150} \quad \therefore \quad 2b = 1^\circ\ 38'$$
$$b = 0\ 49$$

The other answers are:

8-inch con. rifle,	$a = 1^\circ\ 32'$	$b = 1^\circ\ 42'$
Springfield rifle,	3 04	4 30

Example 38.—Compute the striking velocity, time of flight, summit velocity, angle of departure, angle of fall, and coördinates of the summit, for the 2090-yard trajectory of the 8-inch B. L. R.

Digitized by Google

Take data from the table on page 14, and use Equations (8), (5), (28), (29), (30), (31), and (32) in the order named.

ANSWERS:

$v = 1643.44$ f. s.
$T = 3.21$ sec.
$v_0 = 1785.6$ f. s.
$a = 1^\circ\ 43'$
$b = 1^\circ\ 55'$
$x_0 = 3229$ ft.
$y_0 = 49.37$ ft.

The learner should not leave the last five examples until every detail of the calculations has been mastered, as they illustrate all the most important work required in computing range tables for particular guns. They also illustrate the superior flatness of the trajectories of high-power guns over those of less power, and especially in the descending branch where flatness is of the greatest importance. This is shown not only by the greater angle of fall relative to the angle of departure, in the low-power guns, and the greater maximum altitude of the trajectory, but also by the fact that this maximum altitude is carried nearer to the target, thus adding to the general steepness of the descending branch. For the same range, the maximum ordinate is a fair measure of the flatness of a trajectory, but not for different ranges, as is illustrated by Examples 36 and 38, where it is seen that the maximum ordinates of the 1000-yard trajectory of the Springfield rifle and the 2090-yard trajectory of the 8-inch B. L. R., have the same length, though the latter trajectory is evidently much flatter than the former, on account of its greater length.

Flatness of trajectory.—The flatness of trajectories for moderate ranges can best be appreciated by drawing them to scale, when it will be found difficult in many cases to keep the lines representing the trajectory and the horizontal range from running into each other, not only near the terminal points but throughout their whole extent. For example, suppose we select a scale of 12 inches for the horizontal range, and determine the corresponding length of the maximum ordinate of the trajectory of Example 34. In this example the range is 3000 feet and maximum ordinate 10.17 feet. If the former be represented on paper by a horizontal line 12 inches in length, how long will the vertical line representing the latter be? We evidently have the proportion

$$3000 : 10.17 :: 12 : 0.04;$$

that is, in our drawing, the highest point of the trajectory above the horizontal line representing the ranges is but one twenty-fifth of an inch; and of course all other points are still nearer. Anyone who should attempt to make this drawing would be willing to concede that for the purpose of deducing practical rules and formulas for the use of gunners we are at liberty to employ either the trajectory or the horizontal range, one for the other, as is most convenient. This is an extreme illustration; but as we have already stated on page 8, it has been clearly proven that when the angle of elevation of a seacoast gun does not exceed about five degrees the curvature of the trajectory need not be considered, but for practical purposes the trajectory may be taken to coincide with the horizontal range. All the formulas thus far given relating to trajectories ignore the curvature of the latter, and assume that the velocity of the projectile at any instant is the same as the velocity of another projectile which, moving horizontally from the muzzle of the gun, always keeps exactly beneath the actual projectile. This, of course, is not strictly correct, and the error increases rapidly with the curvature of the trajectory. This supposition virtually ignores the retarding and accelerating action of gravity upon the projectile and takes into account only its deflecting agency.

Digitized by Google

Modification of formulas for extended ranges.—In all the formulas thus far given, namely, for the horizontal range, time of flight, angle of departure, angle of fall, summit velocity, and coördinates of the summit, these quantities are each expressed as a function of the muzzle and striking velocities. These formulas, as we have seen, are practically correct only when the angle of departure is small, or, what is the same thing, when the trajectory has little curvature and coincides very closely with the horizontal range. It has been found, however, that a slight modification of these formulas will adapt them for angles of departure up to 15°, thus including all cases of direct fire. This modification consists principally in substituting for the striking velocity in all the formulas another velocity, designated by u. The relation between u and v is given by the equation—

$$u = v\frac{\cos b}{\cos a} \text{.....(33);}$$

and, therefore,

$$v = u\frac{\cos a}{\cos b} \text{.....(34).}$$

The formulas as modified are the following:

$$X = C\{S(u) - S(V)\} \text{.....(35).}$$

$$I(u_0) = \frac{A(u) - A(V)}{S(u) - S(V)} = \frac{A(u) - A(V)}{z} \text{.....(36)}$$

$$\sin 2a = C\left\{\frac{A(u) - A(V)}{S(u) - S(V)} - I(V)\right\} = C\{I(u_0) - I(V)\} \text{.....(37).}$$

$$\tan b = \frac{C}{2\cos^2 a}\left\{I(u) - \frac{A(u) - A(V)}{S(u) - S(V)}\right\} = \frac{C}{2\cos^2 a}\{I(u) - I(u_0)\} \text{.....(38).}$$

$$T = \frac{C}{\cos a}\{T(u) - T(V)\} \text{.....(39).}$$

$$x_0 = C\{S(u_0) - S(V)\} \text{.....(40).}$$

$$y_0 = \frac{C^2}{2\cos^2 a}\left\{\frac{x_0}{C} I(u_0) + A(V) - A(u_0)\right\} \text{.....(41).}$$

$$v_0 = u_0 \cos a \text{.....(42).}$$

The learner who has become familiar with the formulas heretofore given involving v should have no difficulty with the above formulas. The only material changes are in the formulas giving angle of fall, time of flight, and maximum ordinate; but these changes introduce no symbols or operations which the learner is not supposed to know something about before taking up the study of this work. The only new formulas are (34) and (42), which give the striking and summit velocities, respectively, when u and u_0 have been determined. We will now give some examples illustrating the use of these formulas. It will be understood that u takes the place of v not only in the above formulas, but also in Tables I and II:

Example 39.—Compute angle of departure, angle of fall, time of flight, striking velocity and coördinates of the summit of the 3000-yard trajectory of the 8-inch converted rifle.

From Equation (35) we have

$$S(u) = \frac{X}{C} + S(V) = z + S(V) \text{.....(43).}$$

Digitized by Google

from which to compute u, which we then employ in all the other formulas, just as before we used v.

$$\log X = 3.95424$$
$$\log C = 0.44909 \qquad \text{(Equation (43).)}$$
$$\log 3200.0 = 3.50515 = \log s$$
$$S(V) = 4808.6$$
$$S(u) = 8008.6 \quad \therefore \quad u = 978.65$$

$$A(u) = 651.31$$
$$A(V) = 157.97 \qquad \text{(Equation (36).)}$$
$$\log 493.34 = 2.69315$$
$$\log z = 3.50515$$
$$\log 0.15417 = 9.18800 = \log I(u_0)$$
$$I(V) = 0.08433$$
$$\log 0.06984 = 8.84410$$
$$\log C = 0.44909 \qquad \text{(Equation (37).)}$$
$$\log \sin 2a = 9.29319 \quad \therefore \quad 2a = 11^\circ\ 20'$$
$$a = 5\ 40$$

$$I(u) = 0.24332$$
$$I(u_0) = 0.15417$$
$$\log 0.08915 = 8.95012$$
$$\log C = 0.44909 \qquad \text{(Equation (38).)}$$
$$\text{a. c. } \log 2 = 9.69897$$
$$\text{a. c. } \log \cos^2 a = 0.00426$$
$$\log \tan b = 9.10244 \quad \therefore \quad b = 7^\circ\ 13'$$

$$T(u) = 5.260$$
$$T(V) = 2.464$$
$$\log 2.795 = 0.44653 \qquad \text{(Equation (39).)}$$
$$\log C = 0.44909$$
$$\text{a. c. } \log \cos a = 0.00213$$
$$\log T = 0.89775 \quad \therefore \quad T = 7.90 \text{ sec.}$$

$$I(u_0) = 0.15417 \quad \therefore \quad u_0 = 1123.86.$$

$$S(u_0) = 6507.6$$
$$S(V) = 4808.6$$
$$\log 1699.0 = 3.23019 \qquad \text{(Equation (40).)}$$
$$\log C = 0.44909$$
$$\log x_0 = 3.67928 \quad \therefore \quad x_0 = 4778 \text{ ft.}$$
$$\log I(u_0) = 9.18800$$
$$\text{a. c. } \log C = 9.55091$$
$$\log 261.93 = 2.41819$$
$$A(V) = 157.97 \qquad \text{(Equation (41).)}$$
$$419.90$$
$$A(u_0) = 356.06$$
$$\log 63.84 = 1.80509$$
$$2 \log C = 0.89818$$
$$\text{a. c. } \log (2 \cos^2 a) = 9.70323$$
$$\log y_0 = 2.40650 \quad \therefore \quad y_0 = 254.97 \text{ ft.}$$

$$\log u = 2.99062$$
$$\log \cos a = 9.99787$$
$$\text{a. c. } \log b = 0.00346$$
$$\log v = 2.99195 \quad \therefore \quad v = 981.6 \text{ f. s.}$$

Digitized by Google

Example 40.—How many inches of steel could the projectile in Example 39 penetrate on striking?

$$\begin{aligned}
\text{Const. log} &= 6.99066-10 \\
\tfrac{1}{3}\log w &= 1.12763 \\
\log v &= 2.99195 \\
&\quad 1.11024 \\
\tfrac{3}{4}\log d &= 0.67732 \\
&\quad 0.43292 \\
&\quad 10 \\
&\quad 7)4.32920 \\
\log e &= 0.61846 \quad \therefore \quad e = 4.15 \text{ inches.}
\end{aligned}$$

Auxiliary tables.—Suppose we consider the following practical example:

Example 41.—The 8-inch converted rifle is so elevated that the angle of departure of the projectile is 5° 40′. What will be the horizontal range?

We know in this case from Example 39 that the range will be 3000 yards. But, supposing we did not know the range, how are we to compute it? We have given the ballistic coefficient C, the muzzle velocity V, and the angle of departure a to compute the horizontal range X. Now the only expression we have for the horizontal range is the following, which has been already used a great many times:

$$X = C\{S(u) - S(V)\}.$$

But in our example we do not know the value of u, though C and V are both given, and we must manage some way to determine u before we can compute X. From Equation (37) we have, by dividing by C and transposing $I(V)$,

$$\frac{A(u) - A(V)}{S(u) - S(V)} = \frac{\sin 2a}{C} + I(V) \text{.....(43).}$$

The value of the second member of this equation can be computed from the data given in the example we are considering. In fact, since it is the value of $I(u_0)$, it has already been computed in solving Example 39, and is 0.15417. We therefore have

$$\frac{A(u) - A(V)}{S(u) - S(V)} = 0.15417,$$

and this is as far as we can go in determining u directly. The only way we can get u from this equation is by repeated trials — that is, by assuming a value for u — aided by our best judgment in making the assumption—taking its A and S functions from the ballistic table, subtracting and dividing as directed by the formula and comparing the quotient with what it should be, namely, 0.15417. By repeated trials, guided by certain rules, we soon get the correct value of u and then the value of X. But this is at best a tedious process, and fortunately has been rendered unnecessary by the construction of an auxiliary table, just as the extraction of the higher roots of numbers by trial has been superseded by a table of logarithms. The nature of this table is readily understood. Suppose, in determining by trial the value of u, which satisfies the above equation, we had made a great many guesses before getting the right value, giving rise to as many different quotients, some smaller and some larger than 0.15417; and suppose, further, that we had tabulated these different quotients alongside of the corresponding values of u. Then it is easy to see that if we had another similar example to solve, these tabulated values of

$$\frac{A(u) - A(V)}{S(u) - S(V)},$$

might be of great assistance in limiting our guesses of the value of u. And if our table

Digitized by Google

were sufficiently extensive, giving all possible quotients from zero up to the largest quotient required in practice, with the corresponding values of u, we should only have to find any given quotient in the table and alongside of it would be found the value of u, without any calculation. Table A, which follows Table I, and which applies only to rifle projectiles, embodies a like idea. In this table we have selected a number of muzzle velocities 50 f. s. apart, ranging from 1200 f. s. to 2200 f. s., and for each of these velocities have computed the values of

$$\frac{A(u) - A(V)}{z} - I(V) = I(u_0) - I(V),$$

in which

$$z = \frac{X}{C},$$

for values of z differing by 100, from $z = 400$ to $z = 6900$. These numbers, which are called "A" are tabulated in each velocity column, by the side of the z to which they belong. For example, what is the value of A when $V = 1650$ f. s. and $z = 4200$? Find V at the top of one of the broad columns, and run down this column until the line of figures is reached having 4200 in the z or left-hand column. We here find the number .0760, which is the value of A required. That is,

$$\frac{A(u) - A(V)}{z} - I(V) = .0760$$

when $V = 1650$ and $z = 4200$.

This number was computed as follows: We have (Equation (8))

$$S(u) = z + S(V),$$

remembering always that

$$z = \frac{X}{C}.$$

$$\begin{aligned} z &= 4200.0 \\ S(V) &= \underline{3722.2} \\ S(u) &= 7922.2 \quad \therefore \quad u = 984.9 \end{aligned}$$

$$\begin{aligned} A(u) &= 630.54 \\ A(V) &= \underline{83.52} \\ \log 547.02 &= 2.73800 \\ \log z &= \underline{3.62325} \\ \log 0.13024 &= 9.11475 \\ I(V) &= \underline{0.05427} \\ A &= 0.07597; \end{aligned}$$

or, retaining but four decimals, we have $A = 0.0760$, as above.

If $A = 0.0202$ when $z = 1800$, what is the muzzle velocity? Look for 1800 in the z column and run along the horizontal line until .0202 is reached, and at the top of the column where this is found we have $V = 1850$ f. s.

If A is 0.1208 when $V = 1400$ f. s., what is the value of z? Look for the 1400 velocity column at the top of the page, run down this column until 0.1208 is found, and in the z column we have $z = 4800$.

We will now see what use can be made of these numbers. Referring to Equation (37), it will be seen that the quantity within the brace of the second number is what we have represented by A, so that we have at once

$$\sin 2a = AC \text{.....(44).}$$

Digitized by Google

Now in this equation there are four different ballistic quantities, namely, the angle of departure a, the ballistic coefficient C, and in the factor A, as we have seen, are the muzzle velocity V and the number z, which latter involves the range X, and any three of these being given, we can find, either directly or by Table A, the fourth. We will illustrate this by examples.

Example 42.—What angle of departure must the service projectile of the 8-inch B. L. R. have for a horizontal range of 20,312 feet.

The muzzle velocity of this projectile is 1950 f. s., and in order to take out A from the table we must first compute z.

$$\begin{aligned} \log X &= 4.30776 \\ \log C &= \underline{0.71670} \\ \log z &= 3.59106 \quad \therefore \quad z = 3900. \end{aligned}$$

Now for $z = 3900$ and $V = 1950$, we find from the table $A = 0.0494$

$$\begin{aligned} \log A &= 8.69373 \\ \log C &= \underline{0.71670} \\ \log \sin 2a &= 9.41043 \quad \therefore \quad 2a = 14^\circ\ 54' \\ & \qquad\qquad\qquad\quad a = 7^\circ\ 27' \end{aligned}$$

Example 43.—What is the range of a service projectile fired from the 12-inch B. L. R. with an angle of departure of 7° 33′ 30″?

The data for this example are $V = 2100$ f. s., $a = 7^\circ\ 33'\ 30''$, and $\log C = 0.88740$, and we are required to find X, which, as we have seen, is involved in the number A. The first operation, therefore, is to compute A, and then we can take $z\left(\text{or } \frac{X}{C}\right)$ directly from Table A.

From Equation (44) we have

$$A = \frac{\sin 2a}{C} \text{ .....(45),}$$

by means of which A is found by simple division of given data. By logarithms

$$\log A = \log \sin 2a - \log C$$

$$\begin{aligned} \log \sin 2a = \log \sin 15^\circ\ 7' &= 9.41628 \\ \log C &= \underline{0.88740} \qquad \text{(Equation (45).)} \\ \log A &= 8.52888 \\ A &= 0.0338 \end{aligned}$$

Turning to Table A we find in the 2100 velocity column that 0.0338 is on the same line as 3300 in the z column. Therefore

$$z = \frac{X}{C} = 3300.$$

and

$$X = 3300\ C.$$

$$\begin{aligned} \log 3300 &= 3.51851 \\ \log C &= \underline{0.88740} \\ \log X &= 4.40591 \\ X &= 25463 \text{ ft.} = 8488 \text{ yds.} \end{aligned}$$

Example 44.—The range of a service projectile fired from the 3.6-inch B. L. field gun, with an angle of departure of 4° 37′ was 2572 yards. What was the muzzle velocity?

Digitized by Google

We have given $X = 2572$ yards $= 7716$ feet, $a = 4° 37'$ and $\log C = 0.23418$. The operations consist in computing z and A and then taking V from Table A.

$$\log X = 3.88739$$
$$\log C = \underline{0.23418}$$
$$\log z = \overline{3.65321} \quad \therefore \quad z = 4500.$$

$$\log \sin 2a = \log \sin 9° 14' = 9.20535 \qquad \text{(Equation (44).)}$$
$$\log C = \underline{0.23418}$$
$$\log A = \overline{8.97117} \quad \therefore \quad A = 0.0936.$$

We now find 4500 in the z column, and running along the horizontal line we find .0936 in the velocity column headed 1550, which is the muzzle velocity required.

Example 45.—The 10-inch B. L. R. is so elevated that the angle of departure of the projectile is $6° 23'$. What is the horizontal range?

We have given in this example $V = 1975$ f. s., $a = 6° 23'$ and $\log C = 0.80543$, to determine X. First compute A as already explained.

$$\log \sin 2a = 9.34436$$
$$\log C = \underline{0.80543}$$
$$\log A = \overline{8.53893} \quad \therefore \quad A = .0346.$$

Now with $V = 1975$ and $A = .0346$ we are to take z from Table A and then compute X by the formula

$$X = Cz$$

as before. But here we encounter a difficulty, as there is no 1975 velocity column in the table. The last few examples requiring the use of Table A have been purposely selected so that the values of V, z, and A should be found in the table. But in the great majority of examples occurring in practice this will not be the case, and we must provide a ready means for using Table A for all possible values of these quantities, and this we do by means of the following formulas:

$$A = A_1 + \frac{1}{1000000}\{(z - z_1)\,\Delta_z - 2\,(V - V_1)\,\Delta_v\} \ldots\ldots (46).$$

$$V = V_1 + \frac{100}{2\,\Delta_v}\left\{\frac{z - z_1}{100}\,\Delta_z - (A - A_1)\right\} \ldots\ldots (47).$$

$$z = z_1 + \frac{100}{\Delta_z}\left\{\frac{2(V - V_1)}{100}\,\Delta_v + (A - A_1)\right\} \ldots\ldots (48).$$

In these formulas (which are not half as formidable as they appear at first sight) A_1, V_1, and z_1 are numbers found in Table A, while A, V, and z are those we wish to determine, but which are not given in the table. The symbol Δ_z (read "delta sub z") is the difference between two consecutive tabular values of A for the *same muzzle velocity*, and Δ_v (read "delta sub v") is the difference between two consecutive tabular values of A for the *same value of* z. For example (referring to Table A), if the muzzle velocity is 1450 f. s. and z is 2000, we find $A = .0372$. Now, the muzzle velocity remaining the same, if z is increased to 2100, A becomes .0395; that is, $\Delta_z = .0395 - .0372 = .0023$. But if z remains the same (2000) and V changes from 1450 to 1500, then A decreases from .0372 to .0348, that is by .0024, which is of course Δ_v, or the decrease in A due to an increase of 50 f. s. in V. The significant figures of these differences are given in the table in columns adjacent to and to the right of the velocity columns to which they belong; but in using them in the above formulas these significant figures, and also the significant figures of A and A_1, in the terms within braces, are to be used as whole numbers. We will now illustrate the use of these interpolation formulas by several exam-

Digitized by Google

ples; and the learner is advised not to proceed further until he is thoroughly familiar with them.

Given $V = 1718$ and $s = 5723$ to find A from the table.

The nearest less tabular values of V and s are $V_1 = 1700$ and $s_1 = 5700$, and for these values we find from the Table $A_1 = .1125$, $\Delta_s = 30$ and $\Delta_v = 55$. Therefore by Equation (46) we have

$$A = .1125 + \frac{23 \times 30 - 36 \times 55}{1000000} = .1125 + \frac{690 - 1980}{1000000} = .1125 - \frac{1290}{1000000} = .1125 - .001290 =$$

$$.1125 - .0013 = .1112$$

It will be observed that dividing by 1000000 is simply pointing off six places of decimals; and it is always necessary to prefix two or three ciphers, as the case may be, in order to do this. In this example A is less than A_1 on account of the substractive term $2(V - V_1)\Delta_v$ being greater than the additive term $(s - s_1)\Delta_s$. But suppose we take $s = 5780$ instead of 5723, the value of V remaining as it is. We shall now have

$$A = .1125 + \frac{80 \times 30 - 36 \times 55}{1000000} = .1125 + .0004 = .1129.$$

Given $V = 1904.5$ and $s = 4514$. Find A.

Here $V_1 = 1900$, $s_1 = 4500$, $A_1 = .0642$, $\Delta_s = 21$ and $\Delta_v = 32$. Therefore

$$A = \frac{14 \times 21 - 9 \times 32}{1000000} =$$

$$A = .0642 + \frac{14 \times 21 - 9 \times 32}{1000000} = .0642 + .000006 = .0642.$$

That is, the changes in the values of V_1 and s_1 do not affect the value of A_1 in the first four decimals. This means that the *decrease* in the value of A_1 due to the increase of 4.5 in the value of V is balanced by its *increase* due to the increase of 14 in the value of s.

Given $A = .0292$ and $s = 2378.7$. Find V.

Here $s_1 = 2300$, and running along the horizontal line to the right we find the number next less than .0292 to be .0287 which we take for A_1; and this is in the 1800 velocity column. Therefore $V_1 = 1800$. We also have $\Delta_s = 16$ and $\Delta_v = 15$. Substituting these numbers in Equation (47), we have

$$V = 1800 + \frac{100}{30}\{.787 \times 16 - (292 - 287)\} = 1800 + \frac{100}{30}(12.592 - 5) = 1800 + \frac{759.2}{30} =$$

$$1800 + 25.3 = 1825.3 \text{ f. s.}$$

Given $A = .0236$ and $s = 1761.3$ Find V.

Here $s_1 = 1700$, $A_1 = .0224$, $V_1 = 1700$, $\Delta_s = 15$ and $\Delta_v = 13$. Therefore

$$V = 1700 + \frac{100}{26}\{.613 \times 15 - (236 - 224)\} = 1700 + \frac{100}{26}(9.195 - 12) = 1700 - \frac{280.5}{26} = 1689.2 \text{ f. s.}$$

Given $A = .1193$ and $s = 5574.8$. Find V.

Here $s_1 = 5500$, $A_1 = .1181$, $V_1 = 1600$, $\Delta_s = 32$ and $\Delta_v = 59$. Therefore

$$V = 1600 + \frac{100}{118}\{.748 \times 32 - (1193 - 1181)\} = 1600 + \frac{100}{118}\{23.936 - 12\} = 1600 + \frac{1193.6}{118} = 1610.1 \text{ f. s.}$$

Given $A = .0693$ and $s = 2832.9$ Find V.

Here $s_1 = 2800$, $A_1 = .0682$, $V_1 = 1300$, $\Delta_s = 30$ and $\Delta_v = 42$. Therefore

$$V = 1300 + \frac{100}{84}\{.329 \times 30 - (693 - 682)\} = 1300 + \frac{100}{84}(9.87 - 11) = 1300 - \frac{113}{84} = 1298.7 \text{ f. s.}$$

Given $A = .0550$ and $V = 1804.5$ f. s. Find s.

Here $V_1 = 1800$, and running down this velocity column we find the number next less than .0550 to be .0537, which is the value of A_1. Looking to the left on the same horizontal

Digitized by Google

line we find $z_1 = 3700$. We also have $\Delta_z = 21$ and $\Delta_v = 29$. Therefore by Equation (48) we have

$$z = 3700 + \frac{100}{21}\{.09 \times 29 + (550 - 537)\} = 3700 + \frac{100}{21}(2.61 + 13) = 3700 + \frac{1561}{21} = 3774.3.$$

Given $A = .0705$ and $V = 1735.6$ f. s. Find z.

We have $V_1 = 1700$, $A_1 = .0694$, $z_1 = 4100$, $\Delta_z = 25$ and $\Delta_v = 37$. Therefore

$$z = 4100 + \frac{100}{25}\{.712 \times 37 + (705 - 694)\} = 4100 + 4(26.344 + 11) = 4100 + 149 = 4249.$$

When, as in this case, the addition to be made to z_1 exceeds 100, it is better to take the next greater value of z_1 and recompute the value of z.

We now have $V_1 = 1700$, $A_1 = .0719$, $z_1 = 4200$, $\Delta_z = 25$ and $\Delta_v = 39$. Therefore

$$z = 4200 + \frac{100}{25}\{.712 \times 39 + (705 - 719)\} = 4200 + 4(27.768 - 14) = 4200 + 55.1 = 4255.1.$$

It frequently happens that the given muzzle velocity V is one of the velocities found in Table A, as, for example, the muzzle velocity of the 8-inch B. L. R., which is 1950 f. s., and that of the 12-inch B. L. R., which is 2100 f. s. It sometimes happens also, though less frequently, that the given value of z consists of an exact number of hundreds. In either case Equations (46), (47), and (48) are considerably simplified. For if z does not differ from z_1, or V from V_1, then the term containing $z - z_1$ or $V - V_1$ disappears, since each becomes zero. Thus, if $z = z_1$ we have

$$A = A_1 - \frac{2(V - V_1)\Delta_v}{1000000} \quad \text{..... (49).}$$

$$V = V_1 - \frac{100}{2\Delta_v}(A - A_1) \quad \text{.....(50).}$$

and if $V = V_1$,

$$A = A_1 + \frac{(z - z_1)\Delta_z}{1000000} \quad \text{..... (51).}$$

$$z = z_1 + \frac{100}{\Delta_z}(A - A_1) \quad \text{..... (52).}$$

Of course, if $A = A_1$ and $z = z_1$ at the same time no interpolation is necessary, since A can be taken directly from the table as has already been illustrated.

We will now return to Example 45 and complete its solution. We have given in this Example $V = 1975$ and $A = .0346$; and from Table A we find $V_1 = 1950$, $A_1 = .0345$, $z_1 = 3000$, $\Delta_z = 15$ and $\Delta_v = 18$. Therefore

$$z = 3000 + \frac{100}{15}\{.50 \times 18 + (346 - 345)\} = 3066.7$$

$$\log z = 3.48667$$
$$\log C = \underline{0.80543}$$
$$\log X = 4.29210 \quad \therefore X = 19593 \text{ ft.}$$

Example 46.—Compute ranges for the 8-inch B. L. R. corresponding to the following angles of departure: 1°, 2°, 3°, 4°, and 5°.

Computation for $a = 1°$.

$$\log \sin 2a = 8.54282$$
$$\log C = \underline{0.71670}$$
$$\log 0.0067 = \overline{7.82612} = \log. A.$$

$$z = 700 + \frac{100}{10}(67 - 63) = 740 \qquad \text{(Equation (52).)}$$

$$\log z = 2.86923$$
$$\log C = \underline{0.71670}$$
$$\log X = 3.58593 \quad \therefore \quad X = 3854 \text{ ft.} = 1285 \text{ yds.}$$

Digitized by Google

Computation for $a = 2°$

$$\log \sin 2a = 8.84358$$
$$\log C = \underline{0.71670}$$
$$\log 0.0134 = \overline{8.12688} = \log A.$$
$$z = 1300 + \frac{100}{11}(134 - 125) = 1381.8$$

$$\log z = 3.14045$$
$$\log C = \underline{0.71670}$$
$$\log X = 3.85715 \quad \therefore \quad X = 7197 \text{ ft.} = 2399 \text{ yds.}$$

The other answers are:

$$X = 3400 \text{ yds.}$$
$$4278$$
$$5069$$

Example 47.—Compute angles of departure for the 12-inch B. L. R. for ranges 1000 yards apart from 3000 yards to 10000 yards, inclusive.

Computation for $X = 3000$ yds.

$$\log X = 3.95424$$
$$\log C = \underline{0.88740}$$
$$\log 1166.4 = 3.06684 = \log z.$$

$$A = .0089 + \frac{66.4 \times 9}{1000000} = .0095 \qquad \text{(Equation (51).)}$$

$$\log A = 7.97772$$
$$\log C = \underline{0.88740}$$
$$\log \sin 2a = \overline{8.86512} \quad \therefore \quad 2a = 4° 12'$$
$$a = 2\ 06$$

Computation for $X = 4000$ yds.

$$\log X = 4.07918$$
$$\log C = \underline{0.88740}$$
$$\log 1555.2 = 3.19178 = \log z.$$

$$A = .0127 + \frac{55.2 \times 10}{1000000} = .01325$$

$$\log A = 8.12222$$
$$\log C = \underline{0.88740}$$
$$\log \sin 2a = 9.00962 \quad \therefore \quad 2a = 5° 52'$$
$$a = 2\ 56$$

The other answers are:

$$a = 3° 49'$$
$$4\ 46$$
$$5\ 49$$
$$6\ 57$$
$$8\ 12$$
$$9\ 33$$

Table B for angles of fall.—The equation giving the angle of fall (Equation (38)), is

$$\tan b = \frac{C}{2 \cos^2 a}\left\{ I(u) - \frac{A(u) - A(V)}{z} \right\}.$$

Digitized by Google

Now if we call the term within the braces B, and tabulate its values for different values of V and z precisely as was done for A, we shall have

$$\tan b = \frac{BC}{2\cos^2 a}$$

The arrangement of Table B is the same as that of Table A, and the interpolation formulas (46) to (52), inclusive, are as applicable to the former as to the latter by simply changing A and A_1 to B and B_1 wherever they occur. All the other symbols are common to both. The values of B are easily computed when those of A are known. For since by definition

$$A = \frac{A(u) - A(V)}{z} - I(V) = I(u_0) - I(V)$$

and

$$B = I(u) - \frac{A(u) - A(V)}{z} = I(u) - I(u_0),$$

we have by simple addition

$$A + B = I(u) - I(V);$$

and therefore

$$B = I(u) - I(V) - A$$

in which u is determined by the equation

$$S(u) = z + S(V).$$

For example, what is the value of B when $V = 1650$ f. s. and $z = 4200$. On page 40 we have found with this data, $u = 984.9$ and $A = .07597$; and from Table I, $I(u) = .23755$ and $I(V) = .05427$.

Therefore

$$B = .23755 - .05427 - .07597 = .10731;$$

or, retaining but four decimals, $B = .1073$, which is the value of B given in Table B for $V = 1650$ and $z = 4200$.

The expression for $\tan b$ given above can be simplified by combining it with that for $\sin 2a$. See Equation (44).

We have

$$\tan b = \frac{BC}{2\cos^2 a}$$

and

$$\sin 2a = AC.$$

Eliminating C from these equations, we have

$$\tan b = \frac{B}{A}\frac{\sin 2a}{2\cos^2 a} = \frac{B}{A}\cdot\frac{2\sin a\cos a}{2\cos^2 a} = \frac{B\sin a}{A\cos a} \quad \therefore \tan b = \frac{B}{A}\tan a \text{.....(53).}$$

Example 48.—A service projectile is fired from the 8-inch converted rifle with an angle of departure of 7°. What is the range and angle of fall?

We have given $V = 1414$ f. s., $A = 7°$ and $\log C = 0.44909$; and we require X and b. We first compute A by Equation (45); then by means of V, A, and Equation (48) take z from Table A, and with this compute X by the equation

$$X = Cz.$$

Digitized by Google

Next by means of V, z, and Equation (46) take B from Table B, and then compute b by Equation (53).

The calculations are arranged as follows:

$$\log \sin 2a = 9.38368$$
$$\log C = 0.44909$$
$$\log 0.0860 = 8.93459 = \log A.$$

$$z = 3700 + \frac{100}{30}\{.28 \times 50 + (860 - 856)\} = 3760.$$

$$\log z = 3.57519$$
$$\log C = 0.44909$$
$$\log X = 4.02428 \quad \therefore \quad X = 10575 \text{ ft.} = 3525 \text{ yds.}$$

$$B = .1110 + \frac{60 \times 43 - 28 \times 49}{1000000} = .1110 + \frac{1208}{1000000} = .1110 + .0012 = .1122.$$

$$\log B = 9.04999$$
$$\log \tan a = 9.0891$$
$$\text{a. c. } \log A = 1.06541$$
$$\log \tan b = 9.20454 \quad \therefore \quad b = 9^\circ\ 06'.$$

Example 49.—A service projectile fired from the 3.6 inch B. L. R. had a horizontal range of 3500 yards. Compute the angle of departure, angle of fall, striking velocity, and time of flight.

We have given $V = 1550$ f. s., $X = 10500$ feet and $\log C = 0.23418$ by which to compute a, b, u, v, and T. First compute z by Equation (24), and then with V, z, and Equation (52) take A from Table A and with this compute a by Equation (44). Next take B from Table B, with the same data and means as used for A, and then compute b by Equation (53). Next compute u by the equation

$$S(u) = z + S(V)$$

and then the striking velocity by Equation (34). Finally compute the time of flight by Equation (39).

COMPUTATIONS.

$$\log X = 4.02119$$
$$\log C = 0.23418$$
$$\log z = 3.78701 \quad \therefore \quad z = 6123.7$$

$$A = .1445 + \frac{23.7 \times 35}{1000000} = 1453$$

$$\log A = 9.16227$$
$$\log C = 0.23418$$
$$\log \sin 2a = 9.39645 \quad \therefore \quad 2a = 14^\circ\ 26'$$
$$a = 7\ 13$$

$$B = .2113 + \frac{23.7 \times 57}{1000000} = .2127$$

$$\log B = 9.32777$$
$$\log \tan a = 9.10252$$
$$\text{a. c. } \log A = 0.83773$$
$$\log \tan b = 9.26802 \quad \therefore \quad b = 10^\circ\ 30'$$

$$z = 6123.7$$
$$S(V) = 4162.2$$
$$S(u) = 10285.9 \quad \therefore \quad u = 838.4$$

Digitized by Google

$$\log u = 2.92345$$
$$\log \cos a = 9.99655$$
$$\log \sec b = 0.00733$$
$$\log v = 2.92733 \quad \therefore \quad v = 845.9 \text{ f. s.}$$
$$T(u) = 7.781$$
$$T(V) = 2.027$$
$$\log 5.754 = 0.75997$$
$$\log C = 0.23418$$
$$\log \sec a = 0.00345$$
$$\log T = 0.99760 \quad \therefore \quad T = 9.945 \text{ sec.}$$

Example 50.—Compute the angles of fall of the various trajectories of Example 46.

Computation for the first trajectory:

$$B = .0068 + \frac{40 \times 11}{1000000} = .0072.$$
$$\log B = 7.85733$$
$$\log \tan a = 8.24192$$
$$\text{a. c. } \log A = 2.17388$$
$$\log \tan b = 8.27313 \quad \therefore \quad b = 1^\circ\, 04'.$$

The other answers are:

$$b = 2^\circ\, 16'$$
$$3\ 37$$
$$5\ 03$$
$$6\ 33$$

Example 51.—Compute the angles of fall of the trajectories of Example 47.

Computation for the 3000-yard trajectory:

$$B = .0099 + \frac{66.4 \times 11}{1000000} = .0106.$$
$$\log B = 8.02531$$
$$\log \tan a = 8.56429$$
$$\text{a. c. } \log A = 2.02228$$
$$\log \tan b = 8.61188 \quad \therefore \quad b = 2^\circ\, 21'.$$

The other answers are:

$$b = 3^\circ\, 23'$$
$$4\ 35$$
$$5\ 59$$
$$7\ 31$$
$$9\ 17$$
$$11\ 20$$
$$13\ 38$$

The part of Table I, designated "*Auxiliary m*", is principally used for computing the coördinates of the summit of a trajectory by a method explained in Problem XIII of the author's handbook. As the method is but little shorter than that already given here, and fully illustrated by Example 39, it has not been deemed advisable to insert it.

The auxiliary tables for spherical projectiles computed by Major John I. Rodgers, 1st Artillery, can be used in connection with Table II, for the solution of examples pertaining to smooth-bore guns, similar to Examples 45–48 for rifled ordnance.

Drift of elongated projectiles.—The grooves (or "rifles") cut in the surface of the bore of a gun, and into which a portion of the copper band which encircles the projectile near its base is forced by the explosion of the charge, are for the purpose of imparting rotation to the projectile about its longer axis. This rotation is necessary to insure stability to the projectile during its flight (to prevent it from "tumbling"); and, also, to keep it moving point foremost, so that it may meet with the least possible resistance from the air. To secure these desirable results requires a high velocity of rotation, or, in other words, the

Digitized by Google

projectile must make a great many revolutions about its axis in a second of time; and this depends upon the twist of the rifling, or the inclination of the grooves to the axis of the bore. In our service the twist is measured by the distance the projectile advances near the muzzle while it turns once about its axis, and is expressed in calibers. For example, the 3″.2 field gun has a twist of rifling of one turn in 30 calibers; that is, the projectile as it emerges from the muzzle turns once about its axis while it advances 30 x 3″.2 = 96 inches, or 8 feet. But we know that this projectile has a muzzle velocity of 1685 f. s. = 210⅝ × 8; and therefore it revolves 210⅝ times per second. In the same way we find that the 8-inch B. L. R. which has a twist of one turn in 25 calibers, imparts to its projectile $\frac{3 \times 1950}{2 \times 25} = 117$ revolutions per second.

The spinning of the projectile about its axis also produces another effect. Experience teaches us that our oblong projectiles (which have a right-handed revolution, like the hands of a watch) generally move or drift away to the right of the target (unless steps are taken to counteract it), even in a calm atmosphere when the lateral motion can not be attributed to the wind. This deviation to the right, which increases with the range, is called drift, and is always provided for in sighting rifled guns by taking so many "points" to the left.

The equation for calculating the drift is similar in form to Equation (23) for the angle of departure. It is the following:

$$\text{Drift} = A \frac{CVX}{\cos^3 a} \left\{ \frac{B(u) - B(V)}{S(u) - S(V)} - M(V) \right\} \quad \text{.....(54).}$$

In this equation A is a numerical factor depending principally upon the form and length of the projectile and the twist of rifling. The symbols $B(u)$, $B(V)$, and $M(V)$ are certain functions of the muzzle and striking velocities whose values and differences are tabulated in the last four columns of Table I. All the remaining symbols are familiar to the learner. The following values of log A for different types of guns and projectiles in our service give the drift (in feet) with considerable accuracy:

Field and siege guns ..... log $A = 5.77409 - 10$.
Seacoast guns ..... log $A = 5.79686 - 10$.
The 8-inch converted rifle . log $A = 5.68831 - 10$.

Example 52.—Compute the drift of a service projectile fired from the 8-inch converted rifle for a range of 3,000 yards.

From Example 39 we find $u = 978.65$, log $(S(u) - S(V)) = \log z = 3.50515$ and $a = 5° 40'$. The work should be arranged as follows:

$$\begin{aligned}
B(u) &= 72.543 \\
B(V) &= 16.962 \\
\log 55.581 &= 1.74493 \\
\log z &= 3.50515 \\
\log 0.01737 &= 8.23978 \\
M(V) &= 0.00830 \\
\log 0.00907 &= 7.95761 \\
\log X &= 3.95424 \\
\log V &= 3.15045 \\
\log C &= 0.44909 \\
\text{a. c. log cos}^3 a &= 0.00638 \\
\text{Const. log} &= 5.68831 \\
\log D &= 1.20006
\end{aligned}$$

$\therefore$ Drift = 16.07 ft.
= 5.36 yds.

If z, u, and a are not known, they must be computed by the methods already given before the drift can be determined.

Digitized by Google

Example 53.—Compute the drift of a service projectile fired from the 12-inch B. L. R. for a range of 7 miles.

Our data are $X = 36{,}960$ feet, $V = 2{,}100$ f. s., and $\log C = 0.88740$; and we have to compute z, u, a, and D, in the order named.

$$\log X = 4.56773$$
$$\log C = 0.88740$$
$$\log 4789.9 = \overline{3.68033} = \log z$$
$$S(V) = 2024.8$$
$$S(u) = \overline{6814.7} \quad \therefore \quad u = 1085.08$$
$$A = .0563 + \frac{89.9 \times 19}{1000000} = .0563 + .0017 = .0580.$$
$$\log A = 8.76343$$
$$\log C = 0.88740$$
$$\log \sin 2a = \overline{9.65083} \quad \therefore \quad 2a = 26^\circ\ 36'$$
$$a = 13\ 18$$
$$B(u) = 43.212$$
$$B(V) = \underline{3.436}$$
$$\log 39.776 = 1.59962$$
$$\log z = \underline{3.68033}$$
$$\log 0.00830 = \overline{7.91929}$$
$$M(V) = \underline{0.00253}$$
$$\log 0.00577 = \overline{7.76118}$$
$$\log X = 4.56773$$
$$\log V = 3.32222$$
$$\log C = 0.88740$$
$$\text{a. c. } \log \cos {}^3a = 0.03542$$
$$\text{const. } \log = \underline{5.79686}$$
$$\log D = 2.37081 \quad \therefore \quad D = 234.86 \text{ ft.}$$
$$= 78.29 \text{ yds.}$$

Range tables.—One of the principal applications of a system of ballistic formulas and tables like the one here presented is to the computation of range tables for the different guns in the service. The learner who has worked out all the examples here given has made a good beginning toward the construction of range tables for the 8-inch converted rifle and 12-inch B. L. R. For example, take the computations which have been made for the 8-inch converted rifle in Examples 2, 25, 35, 37, 39, 40, and 52, and arrange the answers in tabular form, putting the different ranges in the first column, since the distance is the first thing we want to know when preparing to lay a gun upon a distant object. The result is the following table:

PARTIAL RANGE TABLE FOR THE 8-INCH CONVERTED RIFLE.

$V = 1414$ f. s.; $\log C = 0.44909$.

Range in yards.	Angle of departure.	Time of flight in seconds.	Angle of fall.	Striking velocity in foot-seconds.	Penetration in steel, in inches.	Drift in yards.
1000	1° 32′		1° 42′	1218		
1200	1 53	2.79		1185		
1400	2 14	3.30		1153		
1600	2 37	3.83		1123		
1800	3 00	4.37		1095		
2000	3 25	4.93		1071		
3000	5 40	7.90	7 13	982	4.15	5.36

Digitized by Google

The learner will see from this table that he already possesses the requisite knowledge for constructing all the most essential parts of a range table for any of our guns. Before proceeding further he should—as exercises—fill out the blank spaces still remaining, and look over again carefully the examples which have furnished these numbers.

There have been but few range tables computed as yet for our seacoast guns, because most of these latter are still in the experimental stage, as far as suitable powders are concerned. The muzzle velocities that have been published are not final, and may be changed materially, so that a range table prepared with great labor may be out of date as soon as completed. There have recently been some range tables published for the obsolete guns still in the service, notably those contained in Artillery Circular C, of June 23, 1892, and Artillery Memoranda No. 2, of June 28, 1892. In this latter the learner will find on pages 6 and 7 all the results of his own range table.

In all that precedes, the horizontal range has been used. From the definition of this term given in the beginning of Chapter I, it will be seen that the target is supposed to be on a level with the gun. But as our guns are mounted, this is rarely the case; and in laying a gun with a quadrant it will be necessary to make a correction to the angle of elevation, subtracting the angle of depression of the target if it is below the level of the gun; or adding the angle of elevation of the target above the gun when this latter is below the target. It is assumed, however, that all our high-power guns will be pointed by means of the Zalinski sight, or by some sight embodying similar principles. When this sight is used for laying guns all that is necessary is to set the sight to the proper angle for the horizontal range, and then maneuver the gun so that the axis of the telescope points directly to the target. The gun is then correctly laid, the proper correction for difference of level having been made by this procedure in the most perfect manner and without any calculations. To illustrate this fact, suppose we wish to train the 8-inch C. R. on a target 3000 yards distant and 50 feet below the level of the gun. From our range table we find that the angle of departure for 3000 yards is 5° 40′, and if we assume the jump to be 25′ the angle of elevation will be 5° 40′ $-25'$ = 5° 15′. Set the Zalinski sight to this latter angle, and elevate the muzzle until the telescope is horizontal, as shown by the attached level, and traverse the gun into the plane of fire passing through the target. Now, setting aside latteral deviations as having no bearing upon this illustration, and supposing all conditions (muzzle velocity, density of air, weight of projectile, etc.) to be normal, the projectile should strike a target 3000 yards from the gun and at its level, but would pass over the real target 50 feet below. In order to hit this latter it is necessary to lower the muzzle through an angle equal to the angle of depression of the target below the gun; and a moment's consideration will show that this is done by simply pointing the telescope of the sight at the target, the axis of the gun moving through the same angle as the axis of the telescope. The principle, of course, is the same when the target is above the level of the gun.

If it should be necessary to give the elevation with a quadrant, the angle of depression or elevation of the target can be computed with sufficient accuracy by the simple formula

$$\tan \varepsilon = \frac{d}{X}$$

in which d is the distance of the target above or below the level of the gun, X the horizontal range, and ε the angle through which the muzzle of the gun must be moved to compensate for the difference of level. This angle must be subtracted from the tabular angle of elevation when the target is below the level of the gun, and added to it when it is above.

Digitized by Google

Example 54.—In our illustrative example we have $d = 50$ feet, and $X = 9000$ feet; and ε is computed as follows:

$$\log d = 1.69897$$
$$\log X = \underline{3.95424}$$
$$\log \tan \varepsilon = 7.74473 \quad \therefore \quad \varepsilon = 0^\circ\ 19'$$

Subtracting this from 5° 15′ we have 4° 56′ for the correct quadrant elevation.

Correction of range table for variations of muzzle velocity.—To illustrate this subject we will take the range table, already considered, for the 8-inch C. R. This table was computed for a muzzle velocity of 1414 f. s., and of course the angles of departure, striking velocities, etc., are not correct for any other muzzle velocity. Now, suppose a new brand of powder is furnished which, at the proving ground, gave a tolerably uniform velocity of 1440 f. s.: or, it may be, the old brand of powder which, when new, gave 1414 f. s. has deteriorated so that, as shown by the chronograph, it gives but 1400 f. s.—in either case our range table, computed with great labor, is rendered nearly worthless unless it contains within itself a ready means of correction for the new conditions The principal and most pressing correction relates to the angle of departure, and this correction is provided for by computing the changes in the angles of departure for all the different ranges given in the table, due to a change of 50 f. s. in the muzzle velocity, and placing them in a column alongside the angles of departure for ready reference. We take a change of 50 f. s. as the basis of these calculations because it is a convenient number for the formula presently to be given, and, moreover, should be the limit of changes in muzzle velocity.

Referring to the range table for the 8-inch C. R., on page 6 of Artillery Memoranda, No. 2, we find that the fourth column is such as we have just described. The numbers in this column are minutes and hundredths of a minute of arc, and show the corrections that must be made to the corresponding angles of departure for a variation of 50 f. s. in the muzzle velocity. If this velocity is increased 50 f. s. these corrections are to be subtracted, and if diminished by the same amount they are to be added to the angles of departure. If the variation of velocity is not 50 f. s. but some other less number of foot-seconds then the correction is a proportional part of the tabular correction. For example, what is the correction to be made to the angle of departure for a range of 3000 yards, when the muzzle velocity is 1440 f. s.? The variation in muzzle velocity is $1440 - 1414 = 26$. Therefore the correction required is $\frac{26}{50} \times 21.2 = .52 \times 21.2 = 11'$. The angle of departure for this velocity will, therefore, be $5^\circ\ 40' - 11' = 5^\circ\ 29'$.

These corrections were computed by the formula:*

$$\Delta a = \frac{1719\, C \Delta_v}{\cos 2a} \text{.....(55).}$$

In this formula Δa (read "delta a") is the difference between the value of the angle of departure (a) for a muzzle velocity of 1414 f. s. and its value for a muzzle velocity of 1414 ± 50, as has already been fully explained. The symbol Δ_v refers to a difference of 50 f. s. in the muzzle velocity and is taken from the proper coulmn in Table A.

Example 55.—An example will make the application of this formula better understood. What is the value of Δa when $X = 2400$ yards, for the 8-inch C. R.? Of course if we were computing a range table for this gun we should know the value of z, as it would have been computed for other purposes connected with the table, before reaching this stage. But as we do not know it, our first step is to compute it.

$$\log X = 3.85733$$
$$\log C = 0.44909$$
$$\log z = 3.40824$$
$$z = 2560$$

* Ingalls' Handbook, page 250.

Digitized by Google

Now, in Table A, at the intersection of the Δ_r column for $V = 1400$, and the line passing through $z = 2600$ (the two values nearest to those given), we find the number 34. This means .0034, since, as we have already seen, the ciphers were suppressed in the tabulation of these differences. Therefore $\Delta_r = .0034$; and the remaining computations are the following:

$$\log 1719 = 3.23527$$
$$\log C = 0.44909$$
$$\log \Delta_r = 7.53148$$
$$\text{a. c. } \log \cos 2a = 0.00483$$
$$\log \Delta a = 1.22067 \quad \therefore \quad \Delta a = 16'.62.$$

It is sufficient to compute Δa to the nearest minute for all practical purposes.

Correction of range table for variations in the value of the ballistic coefficient.—The variation of the ballistic coefficient is limited to two causes, namely, variation of the weight of the projectile and variation of the density of the air. Our modern projectiles are made with great care, and the maximum variation in weight allowed by the Government is such a small per cent of the entire weight that it has not much *direct* effect upon the angle of elevation for the more important ranges, rarely producing a variation in this angle of more than two minutes, and generally much less. This variation of weight, however, makes itself more felt indirectly by causing the *muzzle velocity* to change by a very perceptible amount. It is evident that for the same weight of charge the heavier the projectile the less is the muzzle velocity and *vice versa*. The variation of muzzle velocity due to a variation of the weight of projectile may be computed by the formula.

$$\Delta V = \frac{7}{16} \frac{\Delta w}{w} V \text{------} (56).$$

Example 56.—As an example of the use of this formula, suppose a charge of 35 pounds of sphero-hexagonal powder in the 8-inch C. R. gives a muzzle velocity of 1414 f. s. to a 180-pound projectile, what muzzle velocity will the same charge give to a projectile weighing 183 pounds?

We have $V = 1414$, $w = 180$, $\Delta w = 3$. Therefore

$$\Delta V = \frac{7 \times 3 \times 1414}{16 \times 180} = 10 \text{ f. s.}$$

That is, the increase of 3 pounds in the weight of this projectile diminishes the muzzle velocity by 10 f. s., making it 1404 f. s. instead of 1414 f. s. A reference to the range table for this gun shows that for a range of 3000 yards a negative variation of 10 f. s. in the muzzle velocity will require an increase of 4'.2 in the angle of departure. For a range of 4000 yards this increase is 5'.9, while for a range of 2000 yards it is but 2'.7.

The variations of the ballistic coefficient due to variations in the density of the air are of more importance than those just considered. We can calculate corrections of the angle of departure for both, however, as follows: Compute and tabulate corrections for changes in C equal to $\frac{1}{10}$ of its value, for all the different ranges required in the table. Then for any given change in C we can take the proportional part of the tabulated correction and apply it to the corresponding angle of departure. Column 3 of the range table so often referred to contains these corrections for the 8-inch C. R. They were computed by the formula*

$$\Delta a = \frac{171.9\, C}{\cos 2a} (B - A) \text{------} (57),$$

in which A and B are taken from Tables A and B for each range. The factor $(B - A)$ can be easily computed without referring to these tables, by means of the relation

$$B - A = I(u) - I(V) - \frac{2 \sin 2a}{C} \text{------} (58),$$

which the learner can deduce for himself from the definitions of A and B.

* Ingalls' Handbook, page 249.

Digitized by Google

We will now show how to use the Δa column of a range table for correcting the angle of departure for a variation of C due to a variation of the density of the air, or, what is the same thing, to a variation of the atmospheric factor F_a. See page 22.

Example 57.—The range table for the 8-inch C. R. shows that for a range of 3,000 yards the angle of departure is 5° 40′ when the air is normal. What will the angle of departure be when the temperature of the air is 90°, and barometer 30 inches? From Table III we find for the given atmospheric conditions, $F_a = 1.059$. Now as C is to be multiplied by this factor, its value will be increased by .059 of itself, while the corrections (Δa) in the third column of the range table were computed for an assumed variation of $\frac{1}{10}$ of C. Therefore the actual variation of C in this case is 0.59 of the assumed variation, and the correction to be applied to the angle of departure will be 0.59 of the tabulated correction, which in our example is 9′.5. Therefore

$$\Delta a = 0.59 \times 9'.5 = 5'.6 \quad \therefore \quad a = 5^\circ\ 40' - 6' = 5^\circ\ 34'.$$

The learner will probably see for himself why the correction of 6′ is subtracted from the angle of departure found in the range table rather than added.

Example 58.—The range table angle of departure for the 8-inch C. R., conditions normal, for a range 2400 yards is 4° 16′. What will it be when the thermometer reads 20°, and barometer 30 inches? Here $F_a = 0.921 = 1 - .079$; that is, the atmospheric conditions reduce the value of C by .079 of itself, or .79 of the tabular reduction. Therefore

$$\Delta a = .79 \times 6'.08 = 5' \quad \therefore \quad a = 4^\circ\ 16' + 5' = 4^\circ\ 21'.$$

Example 59.—Suppose the projectile in the preceding example weighs 183 pounds instead of the range table weight of 180 pounds. What is the angle of departure?

In this case we have

$$C = 0.921 \times \frac{183}{180} = 0.936\ C = (1 - .064)\ C \quad \therefore \quad \Delta a = .64 \times 6'.08 = 4'$$
$$a = 4^\circ\ 16' + 4' = 4^\circ\ 20'.$$

Digitized by Google

TABLE I.

BALLISTIC TABLE FOR OGIVAL-HEADED PROJECTILES.

u.	$S(u)$.	Diff.	$A(u)$.	Diff.	$I(u)$.	Diff.	$T(u)$.	Diff.	$B(u)$.	Diff.	$M(u)$.	Diff.
2800	000.0	1268	0.00	7	0.00000	106	0.000	46	0.000	139	0.00107	6
2750	126.8	1292	0.07	21	0.00106	112	0.046	47	0.139	150	0.00113	6
2700	256.0	1315	0.28	36	0.00218	118	0.093	49	0.289	161	0.00119	7
2650	387.5	1341	0.64	54	0.00336	125	0.142	51	0.450	174	0.00126	7
2600	521.6	1367	1.18	71	0.00461	133	0.193	53	0.624	188	0.00133	8
2550	658.3	1393	1.89	93	0.00594	140	0.246	56	0.812	203	0.00141	9
2500	797.6	1422	2.82	115	0.00734	149	0.302	57	1.015	220	0.00150	10
2450	939.8	1452	3.97	140	0.00883	160	0.359	60	1.235	239	0.00160	10
2400	1085.0	1481	5.37	166	0.01043	169	0.419	62	1.474	260	0.00170	11
2350	1233.1	1514	7.03	197	0.01212	180	0.481	65	1.734	283	0.00181	12
2300	1384.5	1547	9.00	231	0.01392	192	0.546	68	2.017	308	0.00193	13
2250	1539.2	1582	11.31	266	0.01584	205	0.614	72	2.325	337	0.00206	14
2200	1697.4	321	13.97	58	0.01789	43	0.686	14	2.662	71	0.00220	3
2190	1729.5	322	14.55	60	0.01832	44	0.700	15	2.733	72	0.00223	3
2180	1761.7	323	15.15	62	0.01876	44	0.715	15	2.805	74	0.00226	4
2170	1794.0	325	15.77	63	0.01920	44	0.730	15	2.879	75	0.00230	3
2160	1826.5	327	16.40	65	0.01964	46	0.745	15	2.954	77	0.00233	3
2150	1859.2	328	17.05	67	0.02010	46	0.760	15	3.031	78	0.00236	3
2140	1892.0	329	17.72	68	0.02056	46	0.775	16	3.109	79	0.00239	4
2130	1924.9	331	18.40	70	0.02102	47	0.791	15	3.188	81	0.00243	3
2120	1958.0	333	19.10	73	0.02149	48	0.806	16	3.269	83	0.00246	4
2110	1991.3	335	19.83	74	0.02197	49	0.822	16	3.352	84	0.00250	3
2100	2024.8	336	20.57	76	0.02246	49	0.838	16	3.436	86	0.00253	4
2090	2058.4	337	21.33	79	0.02295	50	0.854	16	3.522	87	0.00257	4
2080	2092.1	339	22.12	80	0.02345	51	0.870	16	3.609	89	0.00261	4
2070	2126.0	341	22.92	82	0.02396	51	0.886	17	3.698	91	0.00265	3
2060	2160.1	343	23.74	85	0.02447	52	0.903	17	3.789	93	0.00268	4
2050	2194.4	344	24.59	87	0.02499	53	0.920	17	3.882	94	0.00272	4
2040	2228.8	346	25.46	89	0.02552	54	0.937	17	3.976	96	0.00276	4
2030	2263.4	348	26.35	91	0.02606	54	0.954	17	4.072	99	0.00280	5
2020	2298.2	349	27.26	94	0.02660	55	0.971	17	4.171	100	0.00285	4
2010	2333.1	351	28.20	96	0.02715	57	0.988	17	4.271	102	0.00289	4
2000	2368.2	353	29.16	98	0.02772	57	1.005	18	4.373	104	0.00293	5
1990	2403.5	355	30.14	101	0.02829	57	1.023	18	4.477	107	0.00298	4
1980	2439.0	356	31.15	104	0.02886	59	1.041	18	4.584	108	0.00302	5
1970	2474.6	358	32.19	107	0.02945	60	1.059	18	4.692	111	0.00307	5

Digitized by Google

TABLE I—CONTINUED.

u.	$S(u)$.	Diff.	$A(u)$.	Diff.	$I(u)$.	Diff.	$T(u)$.	Diff.	$B(u)$.	Diff.	$M(u)$.	Diff.
1960	2510.4	360	33.26	109	0.03005	61	1.077	19	4.803	113	0.00312	4
1950	2546.4	362	34.35	113	0.03066	61	1.096	18	4.916	115	0.00316	5
1940	2582.6	363	35.48	115	0.03127	62	1.114	19	5.031	118	0.00321	5
1930	2618.9	366	36.63	118	0.03189	64	1.133	19	5.149	120	0.00326	5
1920	2655.5	367	37.81	121	0.03253	65	1.152	19	5.269	123	0.00331	6
1910	2692.2	370	39.02	124	0.03318	65	1.171	20	5.392	126	0.00337	5
1900	2729.2	371	40.26	127	0.03383	67	1.191	19	5.518	128	0.00342	6
1890	2766.3	374	41.53	130	0.03450	67	1.210	20	5.646	130	0.00348	5
1880	2803.7	375	42.83	133	0.03517	69	1.230	20	5.776	134	0.00353	6
1870	2841.2	377	44.16	137	0.03586	70	1.250	20	5.910	136	0.00359	6
1860	2878.9	380	45.53	140	0.03656	71	1.270	21	6.046	140	0.00365	6
1850	2916.9	382	46.93	143	0.03727	72	1.291	20	6.186	142	0.00371	6
1840	2955.1	383	48.36	147	0.03799	73	1.311	21	6.328	146	0.00377	6
1830	2993.4	386	49.83	151	0.03872	74	1.332	21	6.474	149	0.00383	6
1820	3032.0	388	51.34	155	0.03946	76	1.353	22	6.623	152	0.00389	7
1810	3070.8	390	52.89	158	0.04022	77	1.375	21	6.775	156	0.00396	6
1800	3109.8	392	54.47	162	0.04099	78	1.396	22	6.931	159	0.00402	7
1790	3149.0	394	56.09	167	0.04177	80	1.418	22	7.090	162	0.00409	7
1780	3188.4	396	57.76	171	0.04257	81	1.440	23	7.252	167	0.00416	7
1770	3228.0	399	59.47	174	0.04338	82	1.463	22	7.419	170	0.00423	7
1760	3267.9	401	61.21	179	0.04420	84	1.485	23	7.589	174	0.00430	8
1750	3308.0	403	63.00	183	0.04504	85	1.508	23	7.763	178	0.00438	7
1740	3348.3	406	64.83	188	0.04589	87	1.531	24	7.941	182	0.00445	8
1730	3388.9	409	66.71	193	0.04676	88	1.555	23	8.123	187	0.00453	8
1720	3429.8	410	68.64	197	0.04764	90	1.578	24	8.310	191	0.00461	8
1710	3470.8	413	70.61	202	0.04854	91	1.602	24	8.501	195	0.00469	9
1700	3512.1	415	72.63	207	0.04945	93	1.626	25	8.696	200	0.00478	8
1690	3553.6	418	74.70	213	0.05038	95	1.651	25	8.896	205	0.00486	9
1680	3595.4	420	76.83	218	0.05133	96	1.676	25	9.101	210	0.00495	9
1670	3637.4	423	79.01	223	0.05229	98	1.701	25	9.311	215	0.00504	9
1660	3679.7	425	81.24	228	0.05327	100	1.726	26	9.526	220	0.00513	9
1650	3722.2	428	83.52	234	0.05427	102	1.752	26	9.746	225	0.00522	10
1640	3765.0	430	85.86	241	0.05529	103	1.778	26	9.971	231	0.00532	10
1630	3808.0	433	88.27	246	0.05632	106	1.804	27	10.202	237	0.00542	10
1620	3851.3	436	90.73	252	0.05738	107	1.831	27	10.439	243	0.00552	10
1610	3894.9	438	93.25	259	0.05845	110	1.858	27	10.682	249	0.00562	11
1600	3938.7	220	95.84	132	0.05955	55	1.885	14	10.931	127	0.00573	5
1595	3960.7	221	97.16	133	0.06010	56	1.899	14	11.058	128	0.00578	6
1590	3982.8	222	98.49	135	0.06066	57	1.913	14	11.186	130	0.00584	5

Digitized by Google

TABLE I—CONTINUED.

u.	$S(u)$.	Diff.	$A(u)$.	Diff.	$I(u)$.	Diff.	$T(u)$.	Diff.	$B(u)$.	Diff.	$M(u)$.	Diff.
1585	4005.0	223	99.84	137	0.06123	57	1.927	14	11.316	132	0.00589	6
1580	4027.3	223	101.21	139	0.06180	58	1.941	14	11.448	133	0.00595	5
1575	4049.6	224	102.60	140	0.06238	58	1.955	14	11.581	135	0.00600	6
1570	4072.0	224	104.00	142	0.06296	59	1.969	14	11.716	137	0.00606	6
1565	4094.4	225	105.42	144	0.06355	59	1.983	15	11.853	138	0.00612	6
1560	4116.9	226	106.86	146	0.06414	60	1.998	14	11.991	140	0.00618	6
1555	4139.5	227	108.32	147	0.06474	60	2.012	15	12.131	143	0.00624	6
1550	4162.2	228	109.79	150	0.06534	61	2.027	15	12.274	144	0.00630	6
1545	4185.0	228	111.29	151	0.06595	62	2.042	15	12.418	145	0.00636	6
1540	4207.8	229	112.80	153	0.06657	62	2.057	15	12.563	148	0.00642	6
1535	4230.7	229	114.33	155	0.06719	63	2.072	14	12.711	150	0.00648	7
1530	4253.6	231	115.88	157	0.06782	64	2.086	15	12.861	152	0.00655	6
1525	4276.7	231	117.45	159	0.06846	64	2.101	16	13.013	153	0.00661	7
1520	4299.8	232	119.04	161	0.06910	65	2.117	15	13.166	156	0.00668	6
1515	4323.0	232	120.65	163	0.06975	65	2.132	15	13.322	158	0.00674	7
1510	4346.2	234	122.28	165	0.07040	66	2.147	15	13.480	160	0.00681	7
1505	4369.6	234	123.93	167	0.07106	67	2.162	16	13.640	162	0.00688	7
1500	4393.0	235	125.60	169	0.07173	68	2.178	16	13.802	164	0.00695	7
1495	4416.5	236	127.29	172	0.07241	68	2.194	16	13.966	166	0.00702	7
1490	4440.1	237	129.01	174	0.07309	69	2.210	16	14.132	169	0.00709	7
1485	4463.8	237	130.75	175	0.07378	69	2.226	16	14.301	171	0.00716	8
1480	4487.5	238	132.50	178	0.07447	70	2.242	16	14.472	173	0.00724	7
1475	4511.3	239	134.28	181	0.07517	71	2.258	16	14.645	176	0.00731	8
1470	4535.2	240	136.09	183	0.07588	72	2.274	16	14.821	178	0.00739	7
1465	4559.2	240	137.92	185	0.07660	72	2.290	17	14.999	180	0.00746	8
1460	4583.2	242	139.77	188	0.07732	73	2.307	16	15.179	183	0.00754	8
1455	4607.4	242	141.65	189	0.07805	74	2.323	17	15.362	186	0.00762	8
1450	4631.6	243	143.54	193	0.07879	75	2.340	17	15.548	188	0.00770	8
1445	4655.9	244	145.47	195	0.07954	75	2.357	17	15.736	190	0.00778	8
1440	4680.3	245	147.42	197	0.08029	76	2.374	17	15.926	193	0.00786	8
1435	4704.8	246	149.39	200	0.08105	77	2.391	17	16.119	197	0.00794	8
1430	4729.4	247	151.39	203	0.08182	78	2.408	17	16.316	199	0.00802	8
1425	4754.1	247	153.42	205	0.08260	78	2.425	18	16.515	201	0.00810	9
1420	4778.8	248	155.47	208	0.08338	80	2.443	17	16.716	204	0.00819	9
1415	4803.6	249	157.55	211	0.08418	80	2.460	18	16.920	208	0.00828	9
1410	4828.5	250	159.66	214	0.08498	81	2.478	18	17.128	211	0.00837	9
1405	4853.5	251	161.80	216	0.08579	82	2.496	18	17.339	213	0.00846	9
1400	4878.6	252	163.96	219	0.08661	83	2.514	18	17.552	216	0.00855	9
1395	4903.8	253	166.15	222	0.08744	84	2.532	18	17.768	220	0.00864	10

Digitized by Google

TABLE I—CONTINUED.

u.	$S(u)$.	Diff.	$A(u)$.	Diff.	$I(u)$.	Diff.	$T(u)$.	Diff.	$B(u)$.	Diff.	$M(u)$.	Diff.
1390	4929.1	254	168.37	225	0.08828	85	2.550	18	17.988	223	0.00874	9
1385	4954.5	254	170.62	228	0.08913	86	2.568	19	18.211	226	0.00883	10
1380	4979.9	256	172.90	231	0.08999	87	2.587	18	18.437	229	0.00893	9
1375	5005.5	256	175.21	234	0.09086	87	2.605	19	18.666	233	0.00902	10
1370	5031.1	257	177.55	227	0.09173	89	2.624	19	18.899	236	0.00912	10
1365	5056.8	258	179.92	241	0.09262	89	2.643	19	19.135	239	0.00922	11
1360	5082.6	260	182.33	243	0.09351	91	2.662	19	19.374	244	0.00933	10
1355	5108.6	260	184.76	247	0.09442	91	2.681	19	19.618	246	0.00943	11
1350	5134.6	261	187.23	250	0.09533	93	2.700	19	19.864	251	0.00954	10
1345	5160.7	262	189.73	254	0.09626	93	2.719	20	20.115	254	0.00964	11
1340	5186.9	263	192.27	257	0.09719	94	2.739	19	20.369	258	0.00975	11
1335	5213.2	263	194.84	260	0.09813	95	2.758	20	20.627	262	0.00986	11
1330	5239.5	263	197.44	262	0.09908	96	2.778	20	20.889	261	0.00997	11
1325	5265.8	262	200.06	263	0.10004	97	2.798	20	21.150	267	0.01008	12
1320	5292.0	106	202.69	107	0.10101	39	2.818	8	21.417	110	0.01020	5
1318	5302.6	106	203.76	108	0.10140	39	2.826	8	21.527	109	0.01025	4
1316	5313.2	106	204.84	108	0.10179	40	2.834	8	21.636	110	0.01029	5
1314	5323.8	107	205.92	109	0.10219	40	2.842	8	21.746	109	0.01034	4
1312	5334.5	107	207.01	110	0.10259	40	2.850	8	21.855	110	0.01038	5
1310	5345.2	107	208.11	111	0.10299	40	2.858	8	21.965	112	0.01043	5
1308	5355.9	108	209.22	111	0.10339	41	2.866	9	22.077	113	0.01048	5
1306	5366.7	108	210.33	112	0.10380	41	2.875	8	22.190	114	0.01053	4
1304	5377.5	108	211.45	113	0.10421	41	2.883	9	22.304	115	0.01057	5
1302	5388.3	109	212.58	114	0.10462	41	2.892	8	22.419	116	0.01062	5
1300	5399.2	109	213.72	115	0.10503	41	2.900	8	22.535	116	0.01067	5
1298	5410.1	109	214.87	115	0.10544	42	2.908	9	22.651	118	0.01072	5
1296	5421.0	110	216.02	117	0.10586	42	2.917	8	22.769	118	0.01077	6
1294	5432.0	110	217.19	117	0.10628	42	2.925	9	22.887	120	0.01083	5
1292	5443.0	110	218.36	118	0.10670	43	2.934	8	23.007	120	0.01088	5
1290	5454.0	111	219.54	119	0.10713	43	2.942	8	23.127	121	0.01093	5
1288	5465.1	111	220.73	120	0.10756	43	2.950	9	23.248	122	0.01098	5
1286	5476.2	111	221.93	120	0.10799	43	2.959	9	23.370	124	0.01103	6
1284	5487.3	112	223.13	122	0.10842	44	2.968	9	23.494	124	0.01109	5
1282	5498.5	112	224.35	122	0.10886	44	2.977	8	23.618	125	0.01114	5
1280	5509.7	113	225.57	123	0.10930	44	2.985	9	23.743	126	0.01119	5
1278	5521.0	113	226.80	124	0.10974	45	2.994	9	23.869	127	0.01124	6
1276	5532.3	113	228.04	125	0.11019	45	3.003	9	23.996	129	0.01130	5
1274	5543.6	113	229.29	125	0.11064	45	3.012	9	24.125	129	0.01135	6
1272	5554.9	114	230.54	127	0.11109	45	3.021	9	24.254	130	0.01141	5

Digitized by Google

TABLE I—CONTINUED.

u.	$S(u)$.	Diff.	$A(u)$.	Diff.	$I(u)$.	Diff.	$T(u)$.	Diff.	$B(u)$.	Diff.	$M(u)$.	Diff
1270	5566.3	114	231.81	127	0.11154	46	3.030	9	24.384	131	0.01146	6
1268	5577.7	114	233.08	129	0.11200	46	3.039	9	24.515	132	0.01152	6
1266	5589.1	115	234.37	129	0.11246	46	3.048	9	24.647	134	0.01158	5
1264	5600.6	115	235.66	131	0.11292	46	3.057	9	24.781	134	0.01163	6
1262	5612.1	116	236.97	131	0.11338	47	3.066	9	24.915	136	0.01169	6
1260	5623.7	116	238.28	132	0.11385	47	3.075	9	25.051	136	0.01175	6
1258	5635.3	117	239.60	134	0.11432	47	3.084	10	25.187	138	0.01181	6
1256	5647.0	116	240.94	134	0.11479	48	3.094	9	25.325	139	0.01187	5
1254	5658.6	117	242.28	136	0.11527	48	3.103	10	25.464	140	0.01192	6
1252	5670.3	118	243.64	136	0.11575	48	3.113	9	25.604	141	0.01198	6
1250	5682.1	118	245.00	137	0.11623	48	3.122	9	25.745	142	0.01204	6
1248	5693.9	118	246.37	139	0.11671	49	3.131	10	25.887	144	0.01210	6
1246	5705.7	119	247.76	139	0.11720	49	3.141	9	26.031	144	0.01216	7
1244	5717.6	119	249.15	140	0.11769	50	3.150	10	26.175	146	0.01223	6
1242	5729.5	119	250.55	142	0.11819	50	3.160	9	26.321	147	0.01229	6
1240	5741.4	120	251.97	142	0.11869	50	3.169	10	26.468	148	0.01235	6
1238	5753.4	120	253.39	144	0.11919	50	3.179	10	26.616	150	0.01241	7
1236	5765.4	121	254.83	144	0.11969	51	3.189	9	26.766	151	0.01248	6
1234	5777.5	121	256.27	146	0.12020	51	3.198	10	26.917	152	0.01254	7
1232	5789.6	121	257.73	147	0.12071	52	3.208	10	27.069	153	0.01261	6
1230	5801.7	122	259.20	148	0.12123	52	3.218	10	27.222	155	0.01267	7
1228	5813.9	122	260.68	149	0.12175	52	3.228	10	27.377	156	0.01274	6
1226	5826.1	123	262.17	150	0.12227	53	3.238	10	27.533	157	0.01280	7
1224	5838.4	123	263.67	151	0.12280	53	3.248	10	27.690	159	0.01287	6
1222	5850.7	123	265.18	153	0.12333	53	3.258	10	27.849	160	0.01293	7
1220	5863.0	124	266.71	153	0.12386	53	3.268	10	28.009	161	0.01300	7
1218	5875.4	124	268.24	155	0.12439	54	3.278	10	28.170	163	0.01307	7
1216	5887.8	125	269.79	156	0.12493	54	3.288	11	28.333	164	0.01314	7
1214	5900.3	125	271.35	157	0.12547	55	3.299	10	28.497	166	0.01321	7
1212	5912.8	125	272.92	159	0.12602	55	3.309	10	28.663	167	0.01328	7
1210	5925.3	126	274.51	160	0.12657	55	3.319	10	28.830	168	0.01335	7
1208	5937.9	126	276.11	161	0.12712	56	3.329	11	28.998	170	0.01342	7
1206	5950.5	127	277.72	162	0.12768	56	3.340	10	29.168	172	0.01349	8
1204	5963.2	127	279.34	163	0.12824	57	3.350	11	29.340	173	0.01357	7
1202	5975.9	127	280.97	165	0.12881	57	3.361	10	29.513	174	0.01364	7
1200	5988.6	128	282.92	166	0.12938	57	3.371	11	29.687	176	0.01371	8
1198	6001.4	128	284.28	167	0.12995	58	3.382	11	29.863	177	0.01379	7
1196	6014.2	129	285.95	168	0.13053	58	3.393	11	30.040	179	0.01386	8
1194	6027.1	129	287.63	170	0.13111	58	3.404	11	30.219	181	0.01394	7

Digitized by Google

TABLE I—CONTINUED.

u.	$S(u)$.	Diff.	$A(u)$.	Diff.	$I(u)$.	Diff.	$T(u)$.	Diff.	$B(u)$.	Diff.	$M(u)$.	Diff.
1192	6040.0	130	289.33	171	0.13169	59	3.415	11	30.400	182	0.01401	8
1190	6053.0	130	291.04	172	0.13228	59	3.426	11	30.582	184	0.01409	8
1188	6066.0	131	292.76	174	0.13287	60	3.437	11	30.766	185	0.01417	8
1186	6079.1	131	294.50	175	0.13347	60	3.448	11	30.951	187	0.01425	7
1184	6092.2	131	296.25	177	0.13407	60	3.459	11	31.138	189	0.01432	8
1182	6105.3	132	298.02	178	0.13467	61	3.470	11	31.327	190	0.01440	8
1180	6118.5	132	299.80	179	0.13528	61	3.481	11	31.517	192	0.01448	8
1178	6131.7	133	301.59	181	0.13589	62	3.492	12	31.709	194	0.01456	8
1176	6145.0	133	303.40	182	0.13651	62	3.504	11	31.903	195	0.01464	9
1174	6158.3	134	305.22	184	0.13713	63	3.515	12	32.098	198	0.01473	8
1172	6171.7	134	307.06	185	0.13776	63	3.527	11	32.296	199	0.01481	8
1170	6185.1	135	308.91	186	0.13839	63	3.538	12	32.495	201	0.01489	9
1168	6198.6	135	310.77	188	0.13902	64	3.550	11	32.696	203	0.01498	8
1166	6212.1	135	312.65	190	0.13966	64	3.561	12	32.899	205	0.01506	9
1164	6225.6	136	314.55	191	0.14030	65	3.573	11	33.104	206	0.01515	8
1162	6239.2	136	316.46	193	0.14095	65	3.584	12	33.310	209	0.01523	9
1160	6252.8	69	318.39	97	0.14160	32	3.596	6	33.519	105	0.01532	4
1159	6259.7	69	319.36	98	0.14192	33	3.602	6	33.624	106	0.01536	5
1158	6266.6	68	320.34	98	0.14225	33	3.608	6	33.730	106	0.01541	4
1157	6273.4	69	321.32	98	0.14258	33	3.614	6	33.836	106	0.01545	5
1156	6280.3	69	322.30	98	0.14291	33	3.620	6	33.942	107	0.01550	4
1155	6287.2	69	323.28	99	0.14324	34	3.626	6	34.049	107	0.01554	5
1154	6294.1	69	324.27	99	0.14358	33	3.632	6	34.156	108	0.01559	4
1153	6301.0	69	325.26	100	0.14391	34	3.638	6	34.264	108	0.01563	5
1152	6307.9	69	326.26	100	0.14425	33	3.644	6	34.372	109	0.01568	4
1151	6314.8	70	327.26	101	0.14458	34	3.650	6	34.481	109	0.01572	5
1150	6321.8	70	328.27	101	0.14492	34	3.656	6	34.590	110	0.01577	5
1149	6328.8	69	329.28	101	0.14526	34	3.662	6	34.700	111	0.01582	4
1148	6335.7	70	330.29	102	0.14560	34	3.668	6	34.811	111	0.01586	5
1147	6342.7	70	331.31	102	0.14594	34	3.674	6	34.922	112	0.01591	5
1146	6349.7	70	332.33	103	0.14628	34	3.680	6	35.034	112	0.01596	5
1145	6356.7	70	333.36	103	0.14662	35	3.686	7	35.146	112	0.01601	4
1144	6363.7	70	334.39	104	0.14697	34	3.693	6	35.258	113	0.01605	5
1143	6370.7	71	335.43	104	0.14731	35	3.699	6	35.371	113	0.01610	5
1142	6377.8	70	336.47	104	0.14766	35	3.705	6	35.484	114	0.01615	4
1141	6384.8	71	337.51	105	0.14801	35	3.711	6	35.598	114	0.01619	5
1140	6391.9	71	338.56	105	0.14836	35	3.717	6	35.712	115	0.01624	5
1139	6399.0	71	339.61	106	0.14871	35	3.723	7	35.827	116	0.01629	5
1138	6406.1	71	340.67	106	0.14906	36	3.730	6	35.943	116	0.01634	4

Digitized by Google

TABLE I—CONTINUED.

u.	$S(u)$.	Diff.	$A(u)$.	Diff.	$I(u)$.	Diff.	$T(u)$.	Diff.	$B(u)$.	Diff.	$M(u)$.	Diff.
1137	6413.2	71	341.73	106	0.14942	35	3.736	6	36.059	117	0.01638	5
1136	6420.3	71	342.79	107	0.14977	36	3.742	6	36.176	117	0.01643	5
1135	6427.4	72	343.86	108	0.15013	36	3.748	7	36.293	118	0.01648	5
1134	6434.6	71	344.94	108	0.15049	36	3.755	6	36.411	119	0.01653	5
1133	6441.7	72	346.02	108	0.15085	36	3.761	6	36.530	119	0.01658	4
1132	6448.9	72	347.10	109	0.15121	36	3.767	7	36.649	120	0.01662	5
1131	6456.1	72	348.19	109	0.15157	36	3.774	6	36.769	120	0.01667	5
1130	6463.3	71	349.28	110	0.15193	36	3.780	6	36.889	121	0.01672	5
1129	6470.4	72	350.38	109	0.15229	36	3.786	7	37.010	121	0.01677	5
1128	6477.6	72	351.47	110	0.15265	37	3.793	6	37.131	122	0.01682	5
1127	6484.8	73	352.57	111	0.15302	36	3.799	7	37.253	122	0.01687	5
1126	6492.1	72	353.68	111	0.15338	37	3.806	6	37.375	123	0.01692	5
1125	6499.3	73	354.79	111	0.15375	37	3.812	6	37.498	124	0.01697	6
1124	6506.6	73	355.90	113	0.15412	37	3.818	7	37.622	124	0.01703	5
1123	6513.9	73	357.03	113	0.15449	38	3.825	6	37.746	125	0.01708	5
1122	6521.2	74	358.16	114	0.15487	37	3.831	7	37.871	125	0.01713	5
1121	6528.6	74	359.30	115	0.15524	38	3.838	6	37.996	126	0.01718	5
1120	6536.0	74	360.45	115	0.15562	38	3.844	7	38.122	128	0.01723	5
1119	6543.4	74	361.60	116	0.15600	38	3.851	7	38.250	128	0.01728	6
1118	6550.8	75	362.76	116	0.15638	38	3.858	6	38.378	130	0.01734	5
1117	6558.3	75	363.92	117	0.15676	39	3.864	7	38.508	130	0.01739	6
1116	6565.8	75	365.09	119	0.15715	39	3.871	7	38.638	132	0.01745	5
1115	6573.3	75	366.28	119	0.15754	39	3.878	7	38.770	132	0.01750	6
1114	6580.8	76	367.47	120	0.15793	39	3.885	7	38.902	134	0.01756	5
1113	6588.4	76	368.67	121	0.15832	40	3.892	6	39.036	134	0.01761	6
1112	6596.0	77	369.88	121	0.15872	40	3.898	7	39.170	136	0.01767	5
1111	6603.7	77	371.09	123	0.15912	40	3.905	7	39.306	136	0.01772	6
1110	6611.4	77	372.32	123	0.15952	41	3.912	7	39.442	138	0.01778	6
1109	6619.1	78	373.55	124	0.15993	40	3.919	7	39.580	138	0.01784	6
1108	6626.9	78	374.79	125	0.16033	41	3.926	7	39.718	140	0.01790	5
1107	6634.7	78	376.04	126	0.16074	41	3.933	7	39.858	140	0.01795	6
1106	6642.5	78	377.30	127	0.16115	42	3.940	7	39.998	142	0.01801	6
1105	6650.3	79	378.57	128	0.16157	41	3.947	8	40.140	143	0.01807	6
1104	6658.2	80	379.85	129	0.16198	42	3.955	7	40.283	144	0.01813	5
1103	6666.2	79	381.14	130	0.16240	42	3.962	7	40.427	145	0.01818	6
1102	6674.1	80	382.44	131	0.16282	43	3.969	7	40.572	147	0.01824	6
1101	6682.1	81	383.75	131	0.16325	42	3.976	7	40.719	147	0.01830	6
1100	6690.2	81	385.06	132	0.16367	43	3.983	8	40.866	149	0.01836	6
1099	6698.3	81	386.38	133	0.16410	43	3.991	7	41.015	150	0.01842	7

Digitized by Google

TABLE I—CONTINUED.

u.	$S(u)$.	Diff.	$A(u)$.	Diff.	$I(u)$.	Diff.	$T(u)$.	Diff.	$B(u)$.	Diff.	$M(u)$.	Diff.
1098	6706.4	81	387.71	135	0.16453	44	3.998	8	41.165	151	0.01849	6
1097	6714.5	82	389.06	135	0.16497	44	4.006	7	41.316	152	0.01855	6
1096	6722.7	83	390.41	137	0.16541	44	4.013	8	41.468	153	0.01861	6
1095	6731.0	82	391.78	137	0.16585	44	4.021	8	41.621	155	0.01867	7
1094	6739.2	83	393.15	138	0.16629	45	4.029	7	41.776	156	0.01874	6
1093	6747.5	84	394.53	140	0.16674	45	4.036	8	41.932	157	0.01880	6
1092	6755.9	84	395.93	141	0.16719	45	4.044	7	42.089	158	0.01886	7
1091	6764.3	84	397.34	141	0.16764	46	4.051	8	42.247	160	0.01893	6
1090	6772.7	85	398.75	142	0.16810	46	4.059	8	42.407	161	0.01899	7
1089	6781.2	85	400.17	143	0.16856	46	4.067	8	42.568	162	0.01906	7
1088	6789.7	85	401.60	145	0.16902	46	4.075	8	42.730	164	0.01913	6
1087	6798.2	86	403.05	145	0.16948	47	4.083	8	42.894	165	0.01919	7
1086	6806.8	86	404.50	147	0.16995	47	4.091	7	43.059	166	0.01926	7
1085	6815.4	87	405.97	148	0.17042	47	4.098	8	43.225	168	0.01933	7
1084	6824.1	87	407.45	149	0.17089	48	4.106	8	43.393	169	0.01940	7
1083	6832.8	87	408.94	150	0.17137	48	4.114	8	43.562	170	0.01947	6
1082	6841.5	88	410.44	151	0.17185	48	4.122	8	43.732	172	0.01953	7
1081	6850.3	88	411.95	152	0.17233	49	4.130	8	43.904	173	0.01960	7
1080	6859.1	88	413.47	153	0.17282	49	4.138	8	44.077	175	0.01967	7
1079	6867.9	89	415.00	154	0.17331	49	4.146	9	44.252	176	0.01974	8
1078	6876.8	90	416.54	156	0.17380	49	4.155	8	44.428	177	0.01982	7
1077	6885.8	89	418.10	156	0.17429	50	4.163	9	44.605	179	0.01989	7
1076	6894.7	90	419.66	158	0.17479	50	4.172	8	44.784	180	0.01996	7
1075	6903.7	91	421.24	159	0.17529	51	4.180	9	44.964	182	0.02003	8
1074	6912.8	91	422.83	161	0.17580	51	4.189	8	45.146	184	0.02011	7
1073	6921.9	92	424.44	162	0.17631	51	4.197	9	45.330	185	0.02018	7
1072	6931.1	92	426.06	163	0.17682	51	4.206	8	45.515	186	0.02025	8
1071	6940.3	92	427.69	164	0.17733	52	4.214	9	45.701	188	0.02033	7
1070	6949.5	93	429.33	165	0.17785	52	4.223	9	45.889	190	0.02040	8
1069	6958.8	93	430.98	166	0.17837	53	4.232	9	46.079	191	0.02048	8
1068	6968.1	94	432.64	168	0.17890	53	4.241	9	46.270	193	0.02056	7
1067	6977.5	94	434.32	169	0.17943	53	4.250	9	46.463	194	0.02063	8
1066	6986.9	94	436.01	171	0.17996	53	4.259	9	46.657	196	0.02071	8
1065	6996.3	95	437.72	172	0.18049	54	4.268	9	46.853	198	0 02079	8
1064	7005.8	96	439.44	173	0.18103	55	4.277	9	47.051	199	0.02087	8
1063	7015.4	96	441.17	175	0.18158	55	4.286	9	47.250	201	0.02095	7
1062	7025.0	96	442.92	176	0.18213	55	4.295	9	47.451	203	0.02102	8
1061	7034.6	97	444.68	177	0.18268	55	4.304	9	47.654	205	0.02110	8
1060	7044.3	97	446.45	178	0.18323	56	4.313	9	47.859	207	0.02118	8

Digitized by Google

TABLE I—CONTINUED.

u.	$S(u)$.	Diff.	$A(u)$.	Diff.	$I(u)$.	Diff.	$T(u)$.	Diff.	$B(u)$.	Diff.	$M(u)$.	Diff.
1059	7054.0	98	448.23	180	0.18379	56	4.322	10	48.066	208	0.02126	9
1058	7063.8	98	450.03	181	0.18435	56	4.332	9	48.274	210	0.02135	8
1057	7073.6	99	451.84	182	0.18491	57	4.341	9	48.484	212	0.02143	9
1056	7073.5	99	453.66	184	0.18548	57	4.350	10	48.696	213	0.02152	8
1055	7093.4	100	455.50	186	0.18605	58	4.360	9	48.909	216	0.02160	9
1054	7103.4	100	457.36	187	0.18663	58	4.369	9	49.125	217	0.02169	8
1053	7113.4	100	459.23	189	0.18721	58	4.378	9	49.342	219	0.02177	9
1052	7123.4	101	461.12	190	0.18779	59	4.387	10	49.561	222	0.02186	8
1051	7133.5	102	463.02	192	0.18838	59	4.397	9	49.783	223	0.02194	9
1050	7143.7	102	464.94	193	0.18897	59	4.406	10	50.006	225	0.02203	9
1049	7153.9	102	466.87	194	0.18956	60	4.416	10	50.231	228	0.02212	9
1048	7164.1	103	468.81	196	0.19016	61	4.426	10	50.459	229	0.02221	9
1047	7174.4	103	470.77	197	0.19077	61	4.436	10	50.688	231	0.02230	9
1046	7184.7	104	472.74	199	0.19138	61	4.446	9	50.919	233	0.02239	9
1045	7195.1	105	474.73	201	0.19199	61	4.455	10	51.152	235	0.02248	10
1044	7205.6	105	476.74	203	0.19260	62	4.465	10	51.387	237	0.02258	9
1043	7216.1	105	478.77	204	0.19322	63	4.475	10	51.624	240	0.02267	9
1042	7226.6	106	480.81	206	0.19385	63	4.485	10	51.864	241	0.02276	9
1041	7237.2	107	482.87	208	0.19448	63	4.495	10	52.105	244	0.02285	9
1040	7247.9	107	484.95	209	0.19511	64	4.505	11	52.349	246	0.02294	10
1039	7258.6	107	487.04	211	0.19575	64	4.516	10	52.595	248	0.02304	10
1038	7269.3	108	489.15	213	0.19639	64	4.526	11	52.843	250	0.02314	10
1037	7280.1	109	491.28	214	0.19703	65	4.537	10	53.093	253	0.02324	10
1036	7291.0	109	493.42	216	0.19768	66	4.547	11	53.346	255	0.02334	10
1035	7301.9	110	495.58	218	0.19834	66	4.558	11	53.601	257	0.02344	9
1034	7312.9	110	497.76	219	0.19900	66	4.569	10	53.858	260	0.02353	10
1033	7323.9	111	499.95	222	0.19966	67	4.579	11	54.118	262	0.02363	10
1032	7335.0	111	502.17	223	0.20033	67	4.590	10	54.380	264	0.02373	10
1031	7346.1	112	504.40	225	0.20100	68	4.600	11	54.644	267	0.02383	10
1030	7357.3	112	506.65	226	0.20168	68	4.611	11	54.911	269	0.02393	11
1029	7368.5	113	508.91	229	0.20236	69	4.622	11	55.180	272	0.02404	10
1028	7379.8	113	511.20	230	0.20305	69	4.633	12	55.452	274	0.02414	11
1027	7391.1	114	513.50	232	0.20374	69	4.645	11	55.726	277	0.02425	10
1026	7402.5	115	515.82	235	0.20443	70	4.656	11	56.003	280	0.02435	11
1025	7414.0	115	518.17	237	0.20513	71	4.667	11	56.283	282	0.02446	11
1024	7425.5	116	520.54	238	0.20584	71	4.678	11	56.565	284	0.02457	10
1023	7437.1	116	522.92	240	0.20655	71	4.689	12	56.849	287	0.02467	11
1022	7448.7	117	525.32	243	0.20726	72	4.701	11	57.136	290	0.02478	10
1021	7460.4	117	527.75	245	0.20798	73	4.712	11	57.426	293	0.02488	11

Digitized by Google

TABLE I—CONTINUED.

u.	$S(u)$.	Diff.	$A(u)$.	Diff.	$I(u)$.	Diff.	$T(u)$.	Diff.	$B(u)$.	Diff.	$M(u)$.	Diff.
1020	7472.1	118	530.20	246	0.20871	73	4.723	12	57.719	296	0.02499	11
1019	7483.9	118	532.66	248	0.20944	73	4.735	12	58.015	298	0.02510	12
1018	7495.7	119	535.14	251	0.21017	74	4.747	12	58.313	301	0.02522	12
1017	7507.6	120	537.65	252	0.21091	74	4.759	12	58.614	304	0.02534	11
1016	7519.6	120	540.17	255	0.21165	75	4.771	11	58.918	306	0.02545	12
1015	7531.6	121	542.72	258	0.21240	76	4.782	12	59.224	310	0.02557	12
1014	7543.7	121	545.30	259	0.21316	76	4.794	12	59.534	312	0.02569	11
1013	7555.8	122	547.89	262	0.21392	76	4.806	12	59.846	316	0.02580	12
1012	7568.0	123	550.51	265	0.21468	77	4.818	12	60.162	318	0.02592	11
1011	7580.3	123	553.16	266	0.21545	78	4.830	12	60.480	322	0.02603	12
1010	7592.6	124	555.82	269	0.21623	78	4.842	13	60.802	325	0.02615	12
1009	7605.0	124	558.51	272	0.21701	79	4.855	12	61.127	328	0.02627	13
1008	7617.4	125	561.23	273	0.21780	79	4.867	13	61.455	331	0.02640	12
1007	7629.9	126	563.96	275	0.21859	80	4.880	12	61.786	334	0.02652	13
1006	7642.5	126	566.71	278	0.21939	80	4.892	13	62.120	337	0.02665	12
1005	7655.1	127	569.49	280	0.22019	81	4.905	13	62.457	340	0.02677	12
1004	7667.8	128	572.29	282	0.22100	82	4.918	12	62.797	344	0.02689	13
1003	7680.6	128	575.11	285	0.22182	82	4.930	13	63.141	347	0.02702	12
1002	7693.4	129	577.96	287	0.22264	83	4.943	12	63.488	351	0.02714	13
1001	7706.3	130	580.83	289	0.22347	83	4.955	13	63.839	354	0.02727	12
1000	7719.3	131	583.72	292	0.22430	84	4.968	13	64.193	358	0.02739	13
999	7732.4	132	586.64	295	0.22514	85	4.981	14	64.551	361	0.02752	14
998	7745.6	132	589.59	297	0.22599	85	4.995	13	64.912	364	0.02766	14
997	7758.8	133	592.56	300	0.22684	86	5.008	14	65.276	368	0.02780	13
996	7772.1	133	595.56	303	0.22770	87	5.022	13	65.644	372	0.02793	14
995	7785.4	133	598.59	306	0.22857	87	5.035	13	66.016	376	0.02807	14
994	7798.7	134	601.65	309	0.22944	87	5.048	14	66.392	379	0.02821	13
993	7812.1	134	604.74	311	0.23031	87	5.062	13	66.771	383	0.02834	14
992	7825.5	135	607.85	314	0.23118	88	5.075	14	67.154	386	0.02848	13
991	7839.0	135	610.99	317	0.23206	89	5.089	13	67.540	391	0.02861	14
990	7852.5	136	614.16	317	0.23295	89	5.102	14	67.931	392	0.02875	14
989	7866.7	136	617.33	319	0.23384	90	5.116	14	68.323	394	0.02889	15
988	7879.7	137	620.52	321	0.23474	90	5.130	14	68.717	398	0.02904	14
987	7893.4	137	623.73	323	0.23564	91	5.144	14	69.115	400	0.02918	14
986	7907.1	137	626.96	325	0.23655	91	5.158	13	69.515	403	0.02932	14
985	7920.8	137	630.21	327	0.23746	91	5.171	14	69.918	406	0.02946	15
984	7934.5	138	633.48	329	0.23837	92	5.185	14	70.324	408	0.02961	14
983	7948.3	138	636.77	331	0.23929	92	5.199	14	70.732	412	0.02975	14
982	7962.1	138	640.08	333	0.24021	92	5.213	14	71.144	414	0.02989	15

Digitized by Google

TABLE I—CONTINUED.

u.	$S(u)$.	Diff.	$A(u)$.	Diff.	$I(u)$.	Diff.	$T(u)$.	Diff.	$B(u)$.	Diff.	$M(u)$.	Diff.
981	7975.9	139	643.41	335	0.24113	93	5.227	14	71.558	417	0.03004	14
980	7989.8	139	646.76	336	0.24206	93	5.241	14	71.975	420	0.03018	15
979	8003.7	139	650.12	339	0.24299	93	5.255	15	72.395	423	0.03033	15
978	8017.6	139	653.51	341	0.24392	94	5.270	14	72.818	427	0.03048	16
977	8031.5	140	556.92	343	0.24486	94	5.284	15	73.245	429	0.03064	15
976	8045.5	140	660.35	345	0.24580	95	5.299	14	73.674	432	0.03079	15
975	8059.5	140	663.80	346	0.24675	95	5.313	14	74.106	435	0.03094	15
974	8073.6	141	667.26	349	0.24770	95	5.327	15	74.541	438	0.03109	15
973	8087.6	141	670.75	351	0.24865	96	5.342	14	74.979	441	0.03124	16
972	8101.7	141	674.26	354	0.24961	96	5.356	15	75.420	444	0.03140	15
971	8115.8	141	677.80	355	0.25057	97	5.371	14	75.864	447	0.03155	15
970	8129.9	142	681.35	357	0.25154	97	5.385	15	76.311	450	0.03170	16
969	8144.1	142	684.92	359	0.25251	97	5.400	15	76.761	453	0.03186	16
968	8158.3	142	688.51	361	0.25348	98	5.415	14	77.214	457	0.03202	16
967	8172.5	143	692.12	363	0.25446	98	5.429	15	77.671	460	0.03218	16
966	8186.8	143	695.75	366	0.25544	99	5.444	15	78.131	463	0.03234	16
965	8201.1	143	699.41	368	0.25643	99	5.459	15	78.594	466	0.03250	15
964	8215.4	144	703.09	370	0.25742	99	5.474	15	79.060	470	0.03265	16
963	8229.8	144	706.79	372	0.25841	100	5.489	14	79.530	473	0.03281	16
962	8244.2	144	710.51	375	0.25941	100	5.503	15	80.003	476	0.03297	16
961	8258.6	144	714.26	377	0.26041	101	5.518	15	80.479	479	0.03313	16
960	8273.0	144	718.03	378	0.26142	101	5.533	15	80.958	483	0.03329	17
959	8287.4	145	721.81	381	0.26243	101	5.548	16	81.441	486	0.03346	16
958	8301.9	145	725.62	384	0.26344	102	5.564	15	81.927	490	0.03362	17
957	8316.4	146	729.46	386	0.26446	103	5.579	15	82.417	493	0.03379	17
956	8331.0	146	733.32	388	0.26549	103	5.594	15	82.910	497	0.03396	16
955	8345.6	146	737.20	390	0.26652	103	5.609	16	83.407	500	0.03412	17
954	8360.2	146	741.10	393	0.26755	103	5.625	15	83.907	503	0.03429	17
953	8374.8	147	745.03	395	0.26858	104	5.640	15	84.410	507	0.03446	17
952	8389.5	147	748.98	398	0.26962	105	5.655	16	84.917	511	0.03463	16
951	8404.2	148	752.96	400	0.27067	105	5.671	15	85.428	514	0.03479	17
950	8419.0	148	756.96	402	0.27172	105	5.686	16	85.942	518	0.03496	18
949	8433.8	148	760.98	404	0.27277	106	5.702	16	86.460	521	0.03514	17
948	8448.6	148	765.02	407	0.27383	106	5.718	15	86.981	525	0.03531	18
947	8463.4	149	769.09	409	0.27489	107	5.733	16	87.506	529	0.03549	18
946	8478.3	149	773.18	412	0.27596	107	5.749	16	88.035	533	0.03567	17
945	8493.2	149	777.30	415	0.27703	108	5.765	16	88.568	537	0.03584	18
944	8508.1	150	781.45	417	0.27811	108	5.781	16	89.105	540	0.03602	18
943	8523.1	150	785.62	420	0.27919	108	5.797	15	89.645	544	0.03620	18

Digitized by Google

TABLE I—CONTINUED.

u.	$S(u)$.	Diff.	$A(u)$.	Diff.	$I(u)$.	Diff.	$T(u)$.	Diff.	$B(u)$.	Diff.	$M(u)$.	Diff.
942	8538.1	150	789.82	422	0.28027	109	5.812	16	90.189	547	0.03638	17
941	8553.1	150	794.04	425	0.28136	110	5.828	16	90.736	552	0.03655	18
940	8568.2	151	798.29	427	0.28246	110	5.844	16	91.288	556	0.03673	19
939	8583.3	151	802.56	429	0.28356	111	5.860	17	91.844	559	0.03692	18
938	8598.4	152	806.85	432	0.28467	111	5.877	16	92.403	564	0.03710	19
937	8613.6	152	811.17	435	0.28578	111	5.893	16	92.967	568	0.03729	19
936	8628.8	152	815.52	437	0.28689	112	5.909	17	93.535	572	0.03748	18
935	8644.0	152	819.89	441	0.28801	112	5.926	16	94.107	576	0.03766	19
934	8659.2	153	824.30	443	0.28913	113	5.942	16	94.683	580	0.03785	19
933	8674.5	153	828.73	445	0.29026	114	5.958	16	95.263	584	0.03804	19
932	8689.8	154	833.18	449	0.29140	114	5.974	17	95.847	588	0.03823	18
931	8705.2	154	837.67	451	0.29254	114	5.991	16	96.435	592	0.03841	19
930	8720.6	154	842.18	453	0.29368	115	6.007	17	97.027	596	0.03860	20
929	8736.0	155	846.71	456	0.29483	115	6.024	17	97.623	601	0.03880	19
928	8751.5	155	851.27	459	0.29598	116	6.041	16	98.224	605	0.03899	20
927	8767.0	155	855.86	462	0.29714	116	6.057	17	98.829	610	0.03919	19
926	8782.5	155	860.48	465	0.29830	117	6.074	17	99.439	615	0.03938	20
925	8798.0	156	865.13	468	0.29947	117	6.091	17	100.05	62	0.0396	2
924	8813.6	156	869.81	470	0.30064	118	6.108	17	100.67	62	0.0398	2
923	8829.2	157	874.51	474	0.30182	118	6.125	16	101.29	63	0.0400	2
922	8844.9	157	879.25	477	0.30300	119	6.141	17	101.92	63	0.0402	2
921	8860.6	157	884.02	479	0.30419	119	6.158	17	102.55	64	0.0404	2
920	8876.3	157	888.81	482	0.30548	120	6.175	17	103.19	64	0.0406	2
919	8892.0	158	893.63	485	0.30658	120	6.192	18	103.83	65	0.0408	2
918	8907.8	159	898.48	488	0.30778	121	6.210	17	104.48	65	0.0410	2
917	8923.7	158	903.36	491	0.30899	121	6.227	18	105.13	66	0.0412	2
916	8939.5	159	908.27	494	0.31020	122	6.245	17	105.79	66	0.0414	2
915	8955.4	159	913.21	497	0.31142	122	6.262	17	106.45	66	0.0416	2
914	8971.3	160	918.18	501	0.31264	123	6.279	18	107.11	67	0.0418	2
913	8987.3	160	923.19	503	0.31387	124	6.297	17	107.78	67	0.0420	2
912	9003.3	160	928.22	506	0.31511	124	6.314	18	108.45	68	0.0422	2
911	9019.3	161	933.28	509	0.31635	125	6.332	17	109.13	68	0.0424	2
910	9035.4	161	948.37	513	0.31760	125	6.349	18	109.81	68	0.0426	2
909	9051.5	161	943.50	515	0.31885	126	6.367	18	110.49	69	0.0428	2
908	9067.6	162	938.65	519	0.32011	126	6.385	18	111.18	70	0.0430	3
907	9083.8	162	953.84	522	0.32137	127	6.403	18	111.88	70	0.0433	2
906	9100.0	162	959.06	525	0.32264	128	6.421	18	112.58	71	0.0435	2
905	9116.2	163	964.31	529	0.32392	128	6.439	18	113.29	71	0.0437	2
904	9132.5	163	969.60	532	0.32520	129	6.457	18	114.00	72	0.0439	2

Digitized by Google

TABLE I—CONTINUED.

u.	$S(u)$.	Diff.	$A(u)$.	Diff.	$I(u)$.	Diff.	$T(u)$.	Diff.	$B(u)$.	Diff.	$M(u)$.	Diff.
903	9148.0	164	974.92	535	0.32649	129	6.475	18	114.72	73	0.0441	3
902	9165.2	164	980.27	538	0.32778	130	6.493	18	115.45	73	0.0444	2
901	9181.6	164	985.65	541	0.32908	130	6.511	18	116.18	74	0.0446	2
900	9198.0	165	991.06	545	0.33038	131	6.529	19	116.92	74	0.0448	3
899	9214.5	165	996.51	548	0.33169	131	6.548	18	117.66	74	0.0451	2
898	9231.0	165	1001.99	552	0.33300	132	6.566	19	118.40	75	0.0453	3
897	9247.5	166	1007.51	555	0.33432	133	6.585	18	119.15	76	0.0456	2
896	9264.1	166	1013.06	559	0.33565	133	6.603	19	119.91	76	0.0458	2
895	9280.7	166	1018.65	562	0.33698	134	6.622	18	120.67	77	0.0460	3
894	9297.3	167	1024.27	565	0.33832	134	6.640	19	121.44	77	0.0463	2
893	9314.0	167	1029.92	569	0.33966	135	6.659	18	122.21	78	0.0465	3
892	9330.7	168	1035.61	573	0.34101	136	6.677	19	122.99	79	0.0468	2
891	9347.5	168	1041.34	576	0.34237	136	6.696	18	123.78	79	0.0470	2
890	9364.3	168	1047.10	580	0.34373	137	6.714	19	124.57	79	0.0472	2
889	9381.1	169	1052.90	583	0.34510	137	6.733	20	125.36	80	0.0474	3
888	9398.0	169	1058.73	587	0.34647	138	6.753	19	126.16	81	0.0477	2
887	9414.9	170	1064.60	592	0.34785	139	6.772	19	126.97	81	0.0479	3
886	9431.9	170	1070.52	595	0.34924	139	6.791	20	127.78	82	0.0482	2
885	9448.9	170	1076.47	598	0.35063	140	6.811	19	128.60	83	0.0484	2
884	9465.9	171	1082.45	602	0.35203	141	6.830	19	129.43	83	0.0486	3
883	9483.0	171	1088.47	606	0.35344	141	6.849	19	130.26	84	0.0489	2
882	9500.1	171	1094.53	609	0.35485	142	6.868	20	131.10	84	0.0491	3
881	9517.2	172	1100.62	613	0.35627	143	6.888	19	131.94	85	0.0494	2
880	9534.4	172	1106.75	617	0.35770	143	6.907	20	132.79	86	0.0496	3
879	9551.6	173	1112.92	621	0.35913	144	6.927	20	133.65	86	0.0499	2
878	9568.9	173	1119.13	625	0.36057	145	6.947	19	134.51	87	0.0501	3
877	9586.2	173	1125.38	629	0.36202	145	6.966	20	135.38	88	0.0504	2
876	9603.5	174	1131.67	633	0.36347	146	6.986	20	136.26	88	0.0506	3
875	9620.9	174	1138.00	637	0.36493	146	7.006	20	137.14	89	0.0509	3
874	9638.3	175	1144.37	641	0.36639	147	7.026	20	138.03	90	0.0512	2
873	9655.8	175	1150.78	645	0.36786	148	7.046	19	138.93	90	0.0514	3
872	9673.3	175	1157.23	649	0.36934	149	7.065	20	139.83	91	0.0517	2
871	9690.8	176	1163.72	653	0.37083	149	7.085	20	140.74	91	0.0519	3
870	9708.4	176	1170.25	657	0.37232	150	7.105	21	141.65	92	0.0522	3
869	9726.0	177	1176.82	662	0.37382	150	7.126	20	142.57	92	0.0525	3
868	9743.7	177	1183.44	665	0.37532	151	7.146	21	143.49	94	0.0528	2
867	9761.4	177	1190.09	670	0.37683	152	7.167	20	144.43	94	0.0530	3
866	9779.1	178	1196.79	675	0.37835	153	7.187	21	145.37	95	0.0533	3
865	9796.9	178	1203.54	678	0.37988	153	7.208	21	146.32	96	0.0536	3

Digitized by Google

TABLE I—CONTINUED.

u.	$S(u)$.	Diff.	$A(u)$.	Diff.	$I(u)$.	Diff.	$T(u)$.	Diff.	$B(u)$.	Diff.	$M(u)$.	Diff.
864	9814.7	179	1210.32	683	0.38141	154	7.229	20	147.28	96	0.0539	3
863	9832.6	179	1217.15	687	0.38295	155	7.249	21	148.24	98	0.0542	2
862	9850.5	179	1224.02	691	0.38450	156	7.270	20	149.22	98	0.0544	3
861	9868.4	180	1230.93	696	0.38606	156	7.290	21	150.20	99	0.0547	3
860	9886.4	180	1237.89	700	0.38762	157	7.311	21	151.19	99	0.0550	3
859	9904.4	181	1244.89	705	0.38919	158	7.332	22	152.18	100	0.0553	3
858	9922.5	181	1251.94	710	0.39077	158	7.354	21	153.18	101	0.0556	3
857	9940.6	181	1259.04	714	0.39235	159	7.375	21	154.19	102	0.0559	3
856	9958.7	182	1266.18	718	0.39394	160	7.396	22	155.21	102	0.0562	2
855	9976.9	183	1273.36	723	0.39554	161	7.418	21	156.23	103	0.0564	3
854	9995.2	183	1280.59	728	0.39715	162	7.439	21	157.26	104	0.0567	3
853	10013.5	183	1287.87	732	0.39877	162	7.460	21	158.30	105	0.0570	3
852	10031.8	184	1295.19	737	0.40039	163	7.481	22	159.35	106	0.0573	3
851	10050.2	184	1302.56	742	0.40202	164	7.503	21	160.41	106	0.0576	3
850	10068.6	185	1309.98	746	0.40366	164	7.524	22	161.47	107	0.0579	3
849	10087.1	185	1317.44	752	0.40530	165	7.546	22	162.54	108	0.0582	3
848	10105.6	185	1324.96	756	0.40695	166	7.568	22	163.62	109	0.0585	3
847	10124.1	186	1332.52	761	0.40861	167	7.590	22	164.71	110	0.0588	3
846	10142.7	186	1340.13	766	0.41028	168	7.612	23	165.81	110	0.0591	3
845	10161.3	187	1347.79	771	0.41196	168	7.635	22	166.91	111	0.0594	4
844	10180.0	188	1355.50	776	0.41364	169	7.657	22	168.02	112	0.0598	3
843	10198.8	187	1363.26	781	0.41533	170	7.679	22	169.14	113	0.0601	3
842	10217.5	188	1371.07	786	0.41703	171	7.701	22	170.27	114	0.0604	3
841	10236.3	189	1378.93	791	0.41874	172	7.723	22	171.41	114	0.0607	3
840	10355.2	189	1386.84	796	0.42046	172	7.745	23	172.55	115	0.0610	3
839	10274.1	189	1394.80	802	0.42218	174	7.768	22	173.70	116	0.0613	3
838	10293.0	190	1402.82	807	0.42392	174	7.790	23	174.86	117	0.0616	4
837	10312.0	190	1410.89	812	0.42566	175	7.813	23	176.03	118	0.0620	3
836	10331.0	191	1419.01	817	0.42741	176	7.836	22	177.21	120	0.0623	3
835	10350.1	191	1427.18	823	0.42917	176	7.858	23	178.41	120	0.0626	3
834	10369.2	192	1435.41	828	0.43093	178	7.881	23	179.61	121	0.0629	3
833	10388.4	192	1443.69	833	0.43271	178	2.904	24	180.82	122	0.0632	4
832	10407.6	193	1552.02	839	0.43449	180	7.928	23	182.04	123	0.0636	3
831	10426.9	193	1460.41	844	0.43629	180	7.951	23	183.27	124	0.0639	3
830	10446.2	194	1468.85	850	0.43809	181	7.974	23	184.51	125	0.0642	3
829	10465.6	194	1477.35	855	0.43990	182	7.997	24	185.76	126	0.0645	4
828	10485.0	194	1485.90	861	0.44172	182	8.021	23	187.02	126	0.0649	3
827	10504.4	195	1494.51	867	0.44354	184	8.044	24	188.28	127	0.0652	4
826	10523.9	195	1503.18	872	0.44538	184	8.068	23	189.55	129	0.0656	3

Digitized by Google

TABLE I—CONTINUED.

u.	$S(u)$.	Diff.	$A(u)$.	Diff.	$I(u)$.	Diff.	$T(u)$.	Diff.	$B(u)$.	Diff.	$M(u)$.	Diff.
825	10543.4	196	1511.90	879	0.44722	186	8.091	24	190.84	130	0.0659	4
824	10563.0	197	1520.69	883	0.44908	186	8.115	24	192.14	130	0.0663	3
823	10582.7	197	1529.52	890	0.45094	188	8.139	24	193.44	132	0.0666	4
822	10602.4	197	1538.42	896	0.45282	188	8.163	24	194.76	132	0.0670	3
821	10622.1	198	1547.38	901	0.45470	189	8.187	24	196.08	134	0.0673	4
820	10641.9	198	1556.39	908	0.45659	190	8.211	24	197.42	135	0.0677	4
819	10661.7	199	1565.47	914	0.45849	191	8.235	24	198.77	135	0.0681	3
818	10681.6	200	1574.61	919	0.46040	191	8.259	25	200.12	136	0.0684	4
817	10701.6	200	1583.80	925	0.46231	193	8.284	24	201.48	138	0.0688	4
816	10721.6	200	1593.05	932	0.46424	194	8.308	25	202.86	139	0.0692	3
815	10741.6	201	1602.37	938	0.46618	194	8.333	24	204.25	140	0.0695	4
814	10761.7	201	1611.75	945	0.46812	196	8.357	25	205.65	142	0.0699	4
813	10781.8	202	1621.20	950	0.47008	197	8.382	25	207.07	142	0.0703	4
812	10802.0	202	1630.70	957	0.47205	197	8.407	25	208.49	144	0.0707	3
811	10822.2	203	1640.27	963	0.47402	199	8.432	25	209.93	145	0.0710	4
810	10842.5	203	1649.90	970	0.47601	199	8.457	25	211.38	145	0.0714	4
809	10862.8	204	1659.60	976	0.47800	201	8.482	25	212.83	147	0.0718	4
808	10883.2	204	1669 36	983	0.48001	201	8.507	26	214.30	148	0.0722	4
807	10903.6	205	1679.19	989	0.48202	202	8.533	25	215.78	149	0.0726	4
806	10924.1	205	1689.08	996	0.48404	204	8.558	26	217.27	150	0.0730	4
805	10944.6	206	1699.04	1003	0.48608	204	8.584	26	218.77	151	0.0734	4
804	10965.2	206	1709.07	1009	0.48812	206	8.610	25	220.28	153	0.0738	4
803	10985.8	207	1719.16	1016	0.49018	207	8.635	26	221.81	154	0.0742	4
802	11006.5	207	1729.32	1023	0.49225	207	8.661	26	223.35	155	0.0746	4
801	11027.2	208	1739.55	1029	0.49432	209	8.687	26	224.90	156	0.0750	4
800	11048.0	208	1749.84	1037	0.49641	209	8.713	26	226.46	157	0.0754	4
799	11068.8	209	1760.21	1043	0.49850	211	8.739	26	228.03	158	0.0758	4
798	11089.7	210	1770.64	1051	0.50061	212	8.765	26	229.61	160	0.0762	5
797	11110.7	210	1781.15	1057	0.50278	213	8.791	27	231.21	161	0.0767	4
796	11131.7	210	1791.72	1065	0.50486	214	8.818	26	232.82	163	0.0771	4
795	11152.7	211	1802.37	1073	0.50700	215	8.844	27	234.45	164	0.0775	4
794	11173.8	212	1813.10	1079	0.50915	216	8.871	26	236.09	165	0.0779	4
793	11195.0	212	1823.89	1087	0.51131	217	8.897	27	237.74	167	0.0783	5
792	11216.2	213	1834.76	1094	0.51348	218	8.924	27	239.41	168	0.0788	4
791	11237.5	213	1845.70	1101	0.51566	220	8.951	27	241.09	170	0.0792	4
790	11258.8	215	1856.71	1116	0.51786	222	8.978	27	242.79	171	0.0796	4
789	11280.3	215	1867.87	1121	0.52008	223	9.005	27	244.50	173	0.0800	4
788	11301.8	216	1879.08	1128	0.52231	223	9.032	28	246.23	174	0.0804	5
787	11323.4	216	1890.36	1134	0.52454	224	9.060	27	247.97	175	0.0809	4

Digitized by Google

TABLE I—CONTINUED.

u.	$S(u)$.	Diff.	$A(u)$.	Diff.	$I(u)$.	Diff.	$T(u)$.	Diff.	$B(u)$.	Diff.	$M(u)$.	Diff.
786	11345.0	216	1901.70	1141	0.52678	226	9.087	27	249.72	176	0.0813	4
785	11366.6	216	1913.11	1146	0.52904	226	9.114	28	251.48	178	0.0817	5
784	11388.2	216	1924.57	1153	0.53130	227	9.142	28	253.26	178	0.0822	4
783	11409.8	217	1936.10	1160	0.53357	228	9.170	27	255.04	180	0.0826	5
782	11431.5	218	1947.70	1166	0.53585	228	9.197	28	256.84	181	0.0831	4
781	11453.3	217	1959.36	1172	0.53813	230	9.225	28	258.65	182	0.0835	5
780	11475.0	218	1971.08	1179	0.54043	230	9.253	28	260.47	183	0.0840	5
779	11496.8	218	1982.87	1185	0.54273	231	9.281	28	262.30	185	0.0845	5
778	11518.6	218	1994.72	1192	0.54504	232	9.309	28	264.15	186	0.0850	4
777	11540.4	218	2006.64	1198	0.54736	233	9.337	28	266.01	187	0.0854	5
776	11562.2	219	2018.62	1206	0.54969	234	9.365	29	267.88	189	0.0859	5
775	11584.1	219	2030.68	1212	0.55203	235	9.394	28	269.77	190	0.0864	5
774	11606.0	219	2042.80	1218	0.55438	236	9.422	28	271.67	191	0.0869	5
773	11627.9	220	2054.98	1226	0.55674	237	9.450	29	273.58	192	0.0874	4
772	11649.9	220	2067.24	1232	0.55911	237	9.479	28	275.50	193	0.0878	5
771	11671.9	220	2079.56	1239	0.56148	239	9.507	29	277.43	195	0.0883	5
770	11693.9	221	2091.95	1246	0.56387	239	9.536	29	279.38	196	0.0888	5
769	11716.0	220	2104.41	1253	0.56626	241	9.565	28	281.34	197	0.0893	5
768	11738.0	221	2116.94	1260	0.56867	241	9.593	29	283.31	199	0.0898	4
767	11760.1	222	2129.54	1267	0.57108	242	9.622	29	285.30	200	0.0902	5
766	11782.3	222	2142.21	1274	0.57350	244	9.651	29	287.30	202	0.0907	5
765	11804.5	222	2154.95	1281	0.57594	244	9.680	29	289.32	203	0.0912	5
764	11826.7	222	2167.76	1288	0.57838	245	9.709	29	291.35	204	0.0917	5
763	11848.9	222	2180.64	1295	0.58083	247	9.738	29	293.39	206	0.0922	5
762	11871.1	223	2193.59	1303	0.58330	247	9.767	30	295.45	207	0.0927	5
761	11893.4	223	2206.62	1309	0.58577	248	9.797	29	297.52	208	0.0932	5
760	11915.7	223	2219.71	1317	0.58825	249	9.826	29	299.60	210	0.0937	5
759	11938.0	224	2232.88	1324	0.59074	250	9.855	30	301.70	211	0.0942	5
758	11960.4	224	2246.12	1332	0.59324	251	9.885	29	303.81	213	0.0947	5
757	11982.8	225	2259.44	1339	0.59575	252	9.914	30	305.94	215	0.0952	5
756	12005.3	224	2272.83	1347	0.59827	253	9.944	29	308.09	216	0.0957	6
755	12027.7	225	2286.30	1354	0.60080	254	9.973	30	310.25	217	0.0963	5
754	12050.2	226	2299.84	1361	0.60334	255	10.003	30	312.42	218	0.0968	5
753	12072.8	225	2313.45	1369	0.60589	256	10.033	30	314.60	220	0.0973	5
752	12095.3	226	2327.14	1377	0.60845	258	10.063	30	316.80	222	0.0978	6
751	12117.9	226	2340.91	1384	0.61103	258	10.093	30	319.02	223	0.0984	5
750	12140.5	226	2354.75	1392	0.61361	259	10.123	30	321.25	225	0.0989	5
749	12163.1	227	2368.67	1399	0.61620	260	10.153	31	323.50	226	0.0994	6
748	12185.8	227	2382.66	1408	0.61880	262	10.184	30	325.76	227	0.1000	5

Digitized by Google

TABLE I—CONTINUED.

u.	$S(u)$.	Diff.	$A(u)$.	Diff.	$I(u)$.	Diff.	$T(u)$.	Diff.	$B(u)$.	Diff.	$M(u)$.	Diff.
747	12208.5	227	2396.74	1415	0.62142	262	10.214	30	328.03	230	0.1005	6
746	12231.2	227	2410.89	1423	0.62404	263	10.244	31	330.33	231	0.1011	5
745	12253.9	228	2425.12	1432	0.62667	265	10.275	31	332.64	232	0.1016	6
744	12276.7	229	2439.44	1439	0.62932	266	10.306	30	334.96	234	0.1022	5
743	12299.6	228	2453.83	1447	0.63198	266	10.336	31	337.30	235	0.1027	6
742	12322.4	229	2468.30	1456	0.63464	268	10.367	31	339.65	237	0.1033	5
741	12345.3	229	2482.86	1463	0.63732	269	10.398	31	342.02	239	0.1038	6
740	12368.2	229	2497.49	1472	0.64001	270	10.429	31	344.41	240	0.1044	6
739	12391.1	230	2512.21	1480	0.64271	271	10.460	31	346.81	242	0.1050	5
738	12414.1	230	2527.01	1488	0.64542	272	10.491	31	349.23	244	0.1055	6
737	12437.1	230	2541.89	1497	0.64814	273	10.522	32	351.67	245	0.1061	6
736	12460.1	231	2556.86	1505	0.65087	274	10.554	31	354.12	247	0.1067	5
735	12483.2	231	2571.91	1513	0.65361	276	10.585	31	356.59	249	0.1072	6
734	12506.3	231	2587.04	1521	0.65637	276	10.616	32	459.08	250	0.1078	6
733	12529.4	232	2602.25	1530	0.65913	278	10.648	31	361.58	252	0.1084	6
732	12552.6	232	2617.55	1539	0.66191	279	10.679	32	364.10	254	0.1090	6
731	12575.8	232	2632.94	1547	0.66470	280	10.711	32	366.64	255	0.1096	6
730	12599.0	233	2648.41	1556	0.66750	281	10.743	32	369.19	257	0.1102	6
729	12662.3	233	2663.97	1564	0.67031	282	10.775	32	371.76	259	0.1108	6
728	12645.6	233	2679.61	1573	0.67313	283	10.807	32	374.35	261	0.1114	6
727	12668.9	234	2695.34	1582	0.67596	285	10.839	32	376.96	263	0.1120	6
726	12692.3	233	2711.16	1591	0.67881	286	10.871	32	379.59	264	0.1126	7
725	12715.6	234	2727.07	1600	0.68167	287	10.903	33	382.23	266	0.1133	6
724	12739.0	235	2743.07	1609	0.68454	288	10.936	32	384.89	268	0.1139	6
723	12762.5	235	2759.16	1617	0.68742	289	10.968	33	387.57	269	0.1145	6
722	12786.0	235	2775.33	1627	0.69031	291	11.001	32	390.26	272	0.1151	7
721	12809.5	236	2791.60	1636	0.69323	292	11.033	33	392.98	273	0.1158	6
720	12833.1	236	2807.96	1645	0.69614	293	11.066	33	395.71	275	0.1164	6
719	12856.7	236	2824.41	1655	0·69907	294	11.099	33	398.46	277	0.1170	7
718	12880.3	236	2840.96	1664	0.70201	295	11.132	33	401.23	279	0.1177	6
717	12903.9	237	2857.60	1673	0.70496	297	11.165	33	404.02	281	0.1183	6
716	12927.6	237	2874.33	1682	0.70793	298	11.198	33	406.83	282	0.1189	7
715	12951.3	238	2891.15	1692	0.71091	299	11.231	33	409.65	285	0.1196	6
714	12975.1	238	2908.07	1701	0.71390	301	11.264	33	412.50	287	0.1202	7
713	12998.9	238	2925.08	1711	0.71691	302	11.297	33	415.37	289	0.1209	7
712	13022.7	238	2942.19	1720	0.71993	303	11.330	34	418.26	290	0.1216	6
711	13046.5	239	2959.39	1730	0.72296	304	11.364	34	421.16	293	0.1222	7
710	13070.4	239	2976.69	1740	0.72600	305	11.398	34	424.09	295	0.1229	7
709	13094.3	240	2994.09	1749	0.72905	307	11.432	33	427.04	297	0.1236	7

Digitized by Google

TABLE I—CONTINUED.

u.	$S(u)$.	Diff.	$A(u)$.	Diff.	$I(u)$.	Diff.	$T(u)$.	Diff.	$B(u)$.	Diff.	$M(u)$.	Diff.
708	13118.3	240	3011.58	1759	0.73212	308	11.465	34	430.01	299	0.1243	6
707	13142.3	240	3029.17	1769	0.73520	310	11.499	34	433.00	300	0.1249	7
706	13166.3	240	3046.86	1780	0.73830	311	11.533	34	436.00	303	0.1256	7
705	13190.3	241	3064.66	1789	0.74141	312	11.567	34	439.03	305	0.1263	7
704	13214.4	241	3082.55	1799	0.74453	313	11.601	35	442.08	308	0.1270	7
703	13238.5	242	3100.54	1810	0.74766	315	11.636	34	445.16	309	0.1277	7
702	13262.7	242	3118.64	1820	0.75081	316	11.670	34	448.25	311	0.1284	7
701	13286.9	242	3136.84	1830	0.75397	318	11.704	35	451.36	313	0.1291	7
700	13311.1	242	3155.14	1841	0.75715	319	11.739	35	454.49	315	0.1298	7
699	13335.3	243	3173.55	1851	0.76034	320	11.774	35	457.64	318	0.1305	7
698	13359.6	243	3192.06	1861	0.76354	321	11.809	35	460.82	320	0.1312	7
697	13383.9	244	3210.67	1872	0.76675	323	11.844	35	464.02	322	0.1319	7
696	13408.3	244	3229.39	1883	0.76998	324	11.879	35	467.24	324	0.1326	8
695	13432.7	244	3248.22	1893	0.77322	326	11.914	35	470.48	327	0.1334	7
694	13457.1	245	3267.15	1904	0.77648	327	11.949	35	473.75	329	0.1341	7
693	13481.6	245	3286.19	1914	0.77975	329	11.984	36	477.04	331	0.1348	7
692	13506.1	245	3305.33	1925	0.78304	330	12.020	35	480.35	333	0.1355	8
691	13530.6	246	3324.58	1937	0.78634	332	12.055	36	483.68	336	0.1363	7
690	13555.2	246	3343.95	1947	0.78966	333	12.091	35	487.04	338	0.1370	8
689	13579.8	246	3363.42	1958	0.79299	344	12.126	36	490.42	341	0.1378	7
688	13604.4	247	3383.00	1970	0.79633	336	12.162	36	493.83	343	0.1385	8
687	13629.1	247	3402.70	1980	0.79969	337	12.198	36	497.26	345	0.1393	7
686	13653.8	248	3422.50	1992	0.80306	339	12.234	36	500.71	348	0.1400	8
685	13678.6	248	3442.42	2003	0.80645	340	12.270	36	504.19	350	0.1408	8
684	13703.4	248	3462.45	2015	0.80985	342	12.306	36	507.69	353	0.1416	7
683	13728.2	249	3482.60	2026	0.81327	343	12.342	37	511.22	355	0.1423	8
682	13753.1	249	3502.86	2038	0.81670	345	12.379	36	514.77	357	0.1431	8
681	13778.0	249	3523.24	2049	0.82015	347	12.415	37	518.34	360	0.1439	8
680	13802.9	250	3543.73	2061	0.82362	348	12.452	37	521.94	362	0.1447	8
679	13827.9	250	3564.34	2074	0.82710	349	12.489	37	525.56	365	0.1455	8
678	13852.9	250	3585.07	2084	0.83059	351	12.526	37	529.21	367	0.1463	8
677	13877.9	251	3605.91	2097	0.83410	352	12.563	37	532.88	370	0.1471	8
676	13903.0	251	3626.88	2108	0.83762	354	12.600	37	536.58	373	0.1479	8
675	13928.1	252	3647.96	2121	0.84116	356	12.637	38	540.31	375	0.1487	9
674	13953.3	252	3669.17	2133	0.84472	357	12.675	37	544.06	378	0.1496	8
673	13978.5	252	3690.50	2144	0.84829	359	12.712	38	547.84	381	0.1504	8
672	14003.7	253	3711.94	2157	0.85188	361	12.750	37	551.65	383	0.1512	9
671	14029.0	253	3733.51	2170	0.85549	362	12.787	38	555.48	386	0.1521	8
670	14054.3	253	3755.21	2182	0.85911	363	12.825	38	559.34	389	0.1529	8

Digitized by Google

TABLE I—CONTINUED.

u.	$S(u)$.	Diff.	$A(u)$.	Diff.	$I(u)$.	Diff.	$T(u)$.	Diff.	$B(u)$.	Diff.	$M(u)$.	Diff.
669	14079.6	254	3777.03	2195	0.86274	365	12.863	38	563.23	391	0.1537	9
668	14105.0	254	3798.98	2207	0.86639	367	12.901	38	567.14	394	0.1546	9
667	14130.4	255	3821.05	2219	0.87006	369	12.939	38	571.08	397	0.1555	8
666	14155.9	255	3843.24	2233	0.87375	370	12.977	38	575.05	400	0.1563	9
665	14181.4	255	3865.57	2245	0.87745	372	13.015	38	579.05	403	0.1572	9
664	14206.9	256	3888.02	2258	0.88117	373	13.053	39	583.08	405	0.1581	8
663	14232.5	256	3910.60	2271	0.88490	376	13.092	38	587.13	408	0.1589	9
662	14258.1	256	3933.31	2285	0.88866	377	13.130	39	591.21	411	0.1598	9
661	14283.7	257	3956.16	2297	0.89243	379	14.169	39	595.32	414	0.1607	9
660	14309.4	257	3979.13	2311	0.89622	380	13.208	39	599.46	417	0.1616	9
659	14335.1	258	4002.24	2324	0.90002	382	13.247	39	603.63	419	0.1625	9
658	14360.9	258	4025.48	2338	0.90384	384	13.286	40	607.82	423	0.1634	9
657	14386.7	259	4048.86	2351	0.90768	385	13.326	39	612.05	426	0.1643	9
656	14412.6	259	4072.37	2364	0.91153	388	13.365	39	616.31	429	0.1652	9
655	14438.5	259	4096.01	2378	0.91541	389	13.404	40	620.60	432	0.1661	10
654	14464.4	260	4119.79	2392	0.91930	391	13.444	40	624.92	435	0.1671	9
653	14490.4	260	4143.71	2406	0.92231	394	13.484	40	629.27	438	0.1680	9
652	14516.4	260	4167.77	2419	0.92715	395	13.524	40	633.65	441	0.1689	10
651	14542.4	261	4191.96	2434	0.93110	396	13.564	40	638.06	444	0.1699	9
650	14568.5	261	4216.30	2448	0.93506	398	13.604	40	642.50	447	0.1708	10
649	14594.6	262	4240.78	2462	0.93904	400	13.644	40	646.97	451	0.1718	9
648	14620.8	262	4265.40	2476	0.94304	402	13.684	41	651.48	454	0.1727	10
947	14647.0	262	4290.16	2491	0.94706	404	13.725	41	656.02	458	0.1737	9
646	14673.2	263	4315.07	2505	0.95110	406	13.766	40	660.60	460	0.1746	10
645	14699.5	264	4340.12	2520	0.95516	407	13.806	41	665.20	464	0.1756	10
644	14725.9	264	4365.32	2535	0.95923	410	13.847	41	669.84	467	0.1766	10
643	14752.3	264	4390.67	2549	0.96333	412	13.888	41	674.51	470	0.1776	10
642	14778.7	264	4416.16	2565	0.96745	413	13.929	42	679.21	474	0.1786	10
641	14805.1	265	4441.81	2579	0.97158	416	13.971	41	683.95	477	0.1796	10
640	14831.6	265	4467.60	2595	0.97574	417	14.012	41	688.72	480	0.1806	10
639	14858.1	266	4493.55	2609	0.97991	419	14.053	42	693.52	484	0.1816	11
638	14884.7	266	4519.64	2625	0.98410	421	14.095	42	698.36	488	0.1827	10
637	14911.3	267	4545.89	2641	0.98831	423	14.137	42	703.24	491	0.1837	10
636	14938.0	267	4572.30	2659	0.99254	426	14.179	42	708.15	494	0.1847	11
635	14964.7	267	4598.86	2671	0.99680	427	14.221	42	713.09	498	0.1858	10
634	14991.4	268	4625.57	2687	1.00107	429	14.263	42	718.07	502	0.1868	11
633	15018.2	268	4652.44	2703	1.00536	431	14.305	43	723.09	506	0.1879	11
632	15045.0	269	4679.47	2718	1.00967	434	14.348	42	728.15	509	0.1890	10
631	15071.9	269	4706.65	2735	1.01401	436	14.390	43	733.24	512	0.1900	11

Digitized by Google

TABLE I—CONTINUED.

u.	$S(u)$.	Diff.	$A(u)$.	Diff.	$I(u)$.	Diff.	$T(u)$.	Diff.	$B(u)$.	Diff.	$M(u)$.	Diff.
630	15098.8	270	4734.00	2751	1.01837	437	14.433	43	738.36	516	0.1911	11
629	15125.8	270	4761.51	2767	1.02274	439	14.476	43	743.52	521	0.1922	11
628	15152.8	270	4789.18	2784	1.02713	442	14.519	43	748.73	524	0.1933	11
627	15179.8	271	4817.02	2800	1.03155	443	14.562	43	753.97	528	0.1944	11
626	15206.9	271	4845.02	2816	1.03598	446	14.605	43	759.25	532	0.1955	11
625	15234.0	272	4873.18	2833	1.04044	448	14.648	44	764.57	535	0.1966	11
624	15261.2	272	4901.51	2849	1.04492	451	14.692	43	769.92	540	0.1977	11
623	15288.4	273	4930.00	2867	1.04943	452	14.735	44	775.32	543	0.1988	11
622	15315.7	273	4958.67	2883	1.05395	455	14.779	44	780.75	547	0.1999	12
621	15343.0	273	4987.50	2901	1.05850	457	14.823	44	786.22	551	0.2011	11
620	15370.3	274	5016.51	2918	1.06307	459	14.867	44	791.73	555	0.2022	11
619	15397.7	274	5045.69	2935	1.06766	461	14.911	45	797.28	560	0.2033	12
618	15425.1	275	5075.04	2953	1.07227	463	14.956	44	802.88	563	0.2045	12
617	15452.6	275	5104.57	2970	1.07690	466	15.000	45	808.51	568	0.2057	11
616	15480.1	276	5134.27	2988	1.08156	468	15.045	45	814.19	572	0.2068	12
615	15507.7	276	5164.15	3006	1.08624	471	15.090	45	819.91	576	0.2080	12
614	15535.3	277	5194.21	3023	1.09095	473	15.135	45	825.67	580	0.2092	12
613	15563.0	277	5224.44	3042	1.09568	475	15.180	45	831.47	585	0.2104	12
612	15590.7	277	5254.86	3060	1.10043	477	15.225	45	837.32	588	0.2116	12
611	15618.4	278	5285.46	3078	1.10520	480	15.270	46	843.20	593	0.2128	12
610	15646.2	278	5316.24	3097	1.11000	482	15.316	45	849.13	597	0.2140	12
609	15674.0	279	5347.21	3115	1.11482	484	15.361	46	855.10	602	0.2152	13
608	15701.9	279	5378.36	3135	1.11966	486	15.407	46	861.12	607	0.2165	12
607	15729.8	280	5409.71	3153	1.12452	489	15.453	46	867.19	611	0.2177	13
506	15757.8	280	5441.24	3171	1.12941	492	15.499	47	873.30	615	0.2190	13
605	15785.8	281	5472.95	3191	1.13433	494	15.546	46	879.45	620	0.2203	12
604	15813.9	281	5504.86	3210	1.13927	497	15.592	46	885.65	625	0.2215	13
603	15842.0	281	5536.96	3230	1.14424	499	15.638	47	891.90	630	0.2228	13
602	15870.1	282	5569.26	3249	1.14923	502	15.685	47	898.20	634	0.2241	13
601	15898.3	283	5601.75	3268	1.15425	504	15.732	47	904.54	638	0.2254	13
600	15926.6	283	5634.43	3288	1.15929	506	15.779	47	910.92	643	0.2267	13
599	15954.9	283	5667.31	3309	1.16435	509	15.826	47	917.35	649	0.2280	13
598	15983.2	284	5700.40	3329	1.16944	512	15.873	48	923.84	653	0.2293	14
597	16011.6	285	5733.69	3349	1.17456	514	15.921	47	930.37	658	0.2307	13
596	16040.1	285	5767.18	3369	1.17970	517	15.968	48	936.95	663	0.2320	14
595	16068.6	285	5800.87	3389	1.18487	519	16.016	48	943.58	668	0.2334	13
594	16097.1	286	5834.76	3409	1.19006	522	16.064	49	950.26	674	0.2347	14
593	16125.7	287	5868.85	3431	1.19528	525	16.113	48	957.00	678	0.2361	13
592	16154.4	287	5903.16	3451	1.20053	527	16.161	48	963.78	683	0.2374	14

Digitized by Google

TABLE I—CONTINUED.

u.	$S(u)$.	Diff.	$A(u)$.	Diff.	$I(u)$.	Diff.	$T(u)$.	Diff.	$B(u)$.	Diff.	$M(u)$.	Diff.
591	16183.1	287	5937.67	3472	1.20580	530	16.209	49	970.61	688	0.2388	14
590	16211.8	288	5972.39	3493	1.21110	533	16.258	49	977.49	693	0.2402	14
589	16240.6	288	6007.32	3515	1.21643	535	16 307	49	984.42	699	0.2416	14
588	16269.4	289	6042.47	3536	1.22178	538	16.356	49	991.41	705	0.2430	14
587	16298.3	289	6077.83	3558	1.22716	541	16.405	49	998.46	709	0.2444	15
586	16327.2	290	6113.41	3579	1.23257	544	16.454	50	1005.6	71	0.2459	14
585	16356.2	290	6149.20	3602	1.23801	547	16.504	49	1012.7	72	0.2473	15
584	16385.2	291	6185.22	3624	1.24348	549	16.553	50	1019.9	73	0.2488	14
583	16414.3	291	6221.46	3646	1.24897	552	16.603	50	1027.2	73	0.2502	15
582	16443.4	292	6257.92	3669	1.25449	555	16.653	51	1034.5	73	0.2517	15
581	16472.6	292	6294.61	3691	1.26004	558	16.704	50	1041.8	74	0.2532	15
580	16501.8	293	6331.52	3714	1.26562	561	16.754	51	1049.2	75	0.2547	15
579	16531.1	293	6368.66	3735	1.27123	564	16.805	50	1056.7	76	0.2562	16
578	16560.4	294	6406.01	3762	1.27687	566	16.855	51	1064.3	76	0.2578	15
577	16589.8	294	6443.63	3783	1.28253	570	16.906	52	1071.9	76	0.2593	15
576	16619.2	295	6481.46	3806	1.28823	573	16.958	51	1079.5	77	0.2608	16
575	16648.7	295	6519.52	3830	1.29396	575	17.009	51	1087.2	78	0.2624	16
574	16678.2	296	6557.82	3854	1.29971	579	17.060	52	1095.0	78	0.2640	15
573	16707.8	296	6596.36	3878	1.30550	581	17.112	52	1102.8	79	0.2655	16
572	16737.4	297	6635.14	3902	1.31131	585	17.164	52	1110.7	80	0.2671	16
571	16767.1	298	6674.16	3926	1.31716	588	17.216	52	1118.7	80	0.2687	16
570	16796.9	298	6713.42	3951	1.32304	591	17.268	52	1126.7	81	0.2703	16
569	16826.7	299	6752.93	3975	1.32895	594	17.320	53	1134.8	81	0.2719	16
568	16856.6	299	6792.68	4000	1.33489	597	17.373	52	1142.9	82	0.2735	16
567	16886.5	399	6832.68	4025	1.34086	600	17.425	53	1151.1	83	0.2751	17
566	16916.4	300	6872.93	4050	1.34686	604	17.478	53	1159.4	83	0.2768	16
565	16946.4	301	6913.43	4075	1.35290	607	17.531	53	1167.7	84	0.2784	17
564	16976.5	301	6954.18	4101	1.35897	610	17.584	54	1176.1	85	0.2801	17
563	17006.6	302	6995.19	4127	1.36507	613	17.638	53	1184.6	85	0.2818	17
562	17036.8	302	7036.46	4153	1.37120	616	17.691	54	1193.1	86	0.2835	17
561	17067.0	303	7077.99	4179	1.37736	620	17.745	54	1201.7	86	0.2852	17
560	17097.3	303	7119.78	4205	1.38356	623	17.799	54	1210.3	88	0.2869	17
559	17127.6	304	7161.83	4232	1.38979	627	17.853	55	1219.1	88	0.2886	18
558	17158.0	304	7204.15	4258	1.39606	630	17.908	54	1227.9	88	0.2904	17
557	17188.4	305	7246.73	4285	1.40236	633	17.962	55	1236.7	90	0.2921	18
556	17218.9	305	7289.58	4313	1.40869	637	18.017	55	1245.7	90	0.2939	18
555	17249.4	306	7332.71	4340	1.41506	640	18.072	55	1254.7	91	0.2957	18
554	17280.0	307	7376.11	4367	1.42146	643	18.127	56	1263.8	91	0.2975	18
553	17310.7	307	7419.78	4396	1.42789	647	18.183	55	1272.9	92	0.2993	18

Digitized by Google

TABLE I—CONTINUED.

u.	$S(u)$.	Diff.	$A(u)$.	Diff.	$I(u)$.	Diff.	$T(u)$.	Diff.	$B(u)$.	Diff.	$M(u)$.	Diff.
552	17341.4	308	7463.74	4423	1.43436	651	18.238	56	1282.1	93	0.3011	19
551	17372.2	308	7507.97	4451	1.44087	654	18.294	56	1291.4	94	0.3030	18
550	17403.0	309	7552.48	4480	1.44741	658	18.350	56	1300.8	94	0.3048	19
549	17433.9	309	7597.28	4508	1.45399	661	18.406	56	1310.2	95	0.3067	18
548	17464.8	310	7642.36	4537	1.46060	665	18.462	57	1319.7	96	0.3085	19
547	17495.8	310	7687.73	4566	1.46725	669	18.519	57	1329.3	97	0.3104	19
546	17526.8	311	7733.39	4595	1.47394	672	18.576	57	1339.0	97	0.3123	19
545	17557.9	312	7779.34	4624	1.48066	676	18.633	57	1348.7	99	0.3142	19
544	17589.1	312	7825.58	4654	1.48742	680	18.690	57	1358.6	99	0.3161	20
543	17620.3	313	7872.12	4684	1.49422	684	18.747	58	1368.5	99	0.3181	19
542	17651.6	313	7918.96	4716	1.50106	687	18.805	58	1378.4	101	0.3200	20
541	17682.9	314	7966.12	4743	1.50793	691	18.863	58	1388.5	101	0.3220	20
540	17714.3	315	8013.55	4775	1.51484	695	18.921	58	1398.6	103	0.3240	20
539	17745.8	315	8061.30	4806	1.52179	699	18.979	59	1408.9	103	0.3260	20
538	17777.3	316	8109.36	4837	1.52878	703	19.038	58	1419.2	103	0.3280	21
537	17808.9	316	8157.73	4868	1.53581	706	19.096	59	1429.5	105	0.3301	20
536	17840.5	317	8206.41	4900	1.54287	711	19.155	60	1440.0	106	0.3321	21
535	17872.2	317	8255.41	4932	1.54998	715	19.215	59	1450.6	106	0.3342	21
534	17903.9	318	8304.73	4963	1.55713	718	19.274	60	1461.2	108	0.3363	21
533	17935.7	319	8354.36	4996	1.56431	723	19.334	60	1472.0	108	0.3384	21
532	17967.6	319	8404.32	5029	1.57154	727	19.394	60	1482.8	109	0.3405	22
531	17999.5	320	8454.61	5061	1.57881	731	19.454	60	1493.7	110	0.3427	21
530	18031.5	320	8505.22	5094	1.58612	735	19.514	60	1504.7	110	0.3448	22
529	18063.5	321	8556.16	5128	1.59347	739	19.574	61	1515.7	112	0.3470	21
528	18095.6	322	8607.44	5162	1.60086	744	19.635	61	1526.9	113	0.3491	22
527	18127.8	322	8659.06	5195	1.60830	748	19.696	61	1538.2	113	0.3513	22
526	18160.0	323	8711.01	5229	1.61578	752	19.757	62	1549.5	115	0.3535	22
525	18192.3	324	8763.30	5264	1.62330	756	19.819	62	1561.0	115	0.3557	23
524	18224.7	324	8815.94	5298	1.63086	761	19.881	62	1572.5	117	0.3580	22
523	18257.1	325	8868.92	5333	1.63847	765	19.943	62	1584.2	117	0.3602	23
522	18289.6	325	8922.25	5368	1.64612	769	20.005	62	1595.9	118	0.3625	23
521	18322.1	326	8975.93	5404	1.65381	774	20.067	63	1607.7	120	0.3648	23
520	18354.7	327	9029.97	5439	1.66155	778	20.130	63	1619.7	120	0.3671	23
519	18387.4	327	9084.36	5475	1.66933	783	20.193	63	1631.7	121	0.3694	24
518	18420.1	328	9139.11	5512	1.67716	788	20.256	63	1643.8	122	0.3718	23
517	18452.9	328	9194.23	5548	1.68504	792	20.319	64	1656.0	124	0.3741	24
516	18485.7	329	9249.71	5585	1.69296	796	20.383	64	1668.4	124	0.3765	24
515	18518.6	330	9305.56	5623	1.70092	802	20.447	64	1680.8	126	0.3789	24
514	18551.6	331	9361.79	5660	1.70894	806	20.511	64	1693.4	126	0.3813	25

Digitized by Google

TABLE I—CONTINUED.

u.	$S(u)$.	Diff.	$A(u)$.	Diff.	$I(u)$.	Diff.	$T(u)$.	Diff.	$B(u)$.	Diff.	$M(u)$.	Diff.
513	18584.7	331	9418.39	5699	1.71700	810	20.575	65	1706.0	127	0.3838	24
512	18617.8	332	9475.38	5736	1.72510	816	20.640	65	1718.7	129	0.3862	25
511	18651.0	332	9532.74	5775	1.73326	820	20.705	65	1731.6	130	0.3887	25
510	18684.2	333	9590.49	5813	1.74146	825	20.770	65	1744.6	131	0.3912	25
509	18717.5	334	9648.62	5853	1.74971	830	20.835	66	1757.7	132	0.3937	25
508	18750.9	334	9707.15	5891	1.75801	835	20.901	66	1770.9	133	0.3962	26
507	18784.3	335	9766.06	5932	1.76636	840	20.967	66	1784.2	134	0.3988	26
506	18817.8	366	9825.38	5971	1.77476	845	21.033	66	1797.6	135	0.4014	26
505	18851.4	336	9885.09	6012	1.78321	350	21.099	67	1811.1	136	0.4040	26
504	18885.0	337	9945.21	6053	1.79171	855	21.166	67	1824.7	138	0.4066	26
503	18918.7	338	10005.74	6093	1.80026	860	21.233	67	1838.5	138	0.4092	27
502	18952.5	338	10066.67	6134	1.80886	865	21.300	67	1852.3	140	0.4119	27
501	18986.3	339	10128.01	6177	1.81751	871	21.367	68	1866.3	141	0.4146	27
500	19020.2	340	10189.78	6219	1.82622	876	21.435	68	1880.4	142	0.4173	27
499	19054.2	340	10251.9	626	1.83498	881	21.503	69	1894.6	143	0.4200	28
498	19088.2	341	10314.5	631	1.84379	886	21.572	69	1908.9	145	0.4228	27
497	19122.3	341	10377.6	634	1.85265	892	21.641	69	1923.4	146	0.4255	28
496	19156.4	342	10441.0	639	1.86157	897	21.710	69	1938.0	147	0.4283	29
495	19190.6	343	10504.9	644	1.87054	903	21.779	69	1952.7	148	0.4312	28
494	19224.9	344	10569.3	648	1.87957	908	21.848	70	1967.5	150	0.4340	29
493	19259.3	345	10634.1	652	1.88865	913	21.918	70	1982.5	151	0.4369	29
492	19293.8	345	10699.3	657	1.89778	919	21.988	70	1997.6	152	0.4398	29
491	19328.3	346	10765.0	661	1.90697	925	22.058	70	2012.8	154	0.4427	29
490	19362.9	347	10831.1	665	1.91622	930	22.128	71	2028.2	155	0.4456	30
489	19397.6	347	10897.6	671	1.92552	936	22.199	71	2043.7	156	0.4486	29
488	19432.3	348	10964.7	675	1.93488	942	22.270	71	2059.3	158	0.4515	30
487	19467.1	349	11032.2	679	1.94430	948	22.341	72	2075.1	159	0.4545	31
486	19502.0	349	11100.1	685	1.95378	954	22.413	72	2091.0	161	0.4576	30
585	19536.9	351	11168.6	689	1.96332	960	22.485	72	2107.1	162	0.4606	31
484	19572.0	351	11237.5	695	1.97292	966	22.557	73	2123.3	163	0.4637	31
483	19607.1	351	11307.0	699	1.98258	972	22.630	73	2139.6	164	0.4668	32
482	19642.2	353	11376.9	703	1.99230	977	22.703	73	2156.0	166	0.4700	31
481	19677.5	353	11447.2	709	2.00207	983	22.776	73	2172.6	168	0.4731	32
480	19712.8	354	11518.1	713	2.01190	990	22.849	74	2189.4	169	0.4763	32
479	19748.2	354	11589.4	719	2.02180	996	22.923	74	2206.3	171	0.4795	32
478	19783.6	355	11661.3	724	2.03176	1003	22.997	74	2223.4	172	0.4827	33
477	19819.1	356	11733.7	729	2.04179	1009	23.071	75	2240.6	173	0.4860	33
476	19854.7	357	11806.6	734	2.05188	1015	23.146	75	2257.9	175	0.4893	33
475	19890.4	358	11880.0	739	2.06203	1022	23.221	75	2275.4	177	0.4926	33

Digitized by Google

TABLE I—CONTINUED.

u.	$S(u)$.	Diff.	$A(u)$.	Diff.	$I(u)$.	Diff.	$T(u)$.	Diff.	$B(u)$.	Diff.	$M(u)$.	Diff.
474	19926.2	358	11953.9	745	2.07225	1028	23.296	76	2293.1	179	0.4959	34
473	19962.0	359	12028.4	750	2.08253	1035	23.372	76	2311.0	180	0.4993	34
472	19997.9	360	12103.4	755	2.09288	1041	23.448	76	2329.0	181	0.5027	34
471	20033.9	361	12178.9	760	2.10329	1047	23.524	77	2347.1	183	0.5061	35
470	20070.0	362	12254.9	766	2.11376	1054	23.601	77	2365.4	185	0.5096	35
469	20106.2	362	12331.5	771	2.12430	1061	23.678	77	2383.9	187	0.5131	35
468	20142.4	363	12408.6	777	2.13491	1068	23.755	78	2402.6	188	0.5166	36
467	20178.7	363	12486.3	783	2.14559	1076	23.833	78	2421.4	190	0.5202	35
466	20215.0	365	12564.6	788	2.15635	1082	23.911	78	2440.4	192	0.5237	36
465	20251.5	365	12643.4	794	2.16717	1089	23.989	79	2459.6	194	0.5273	37
464	20288.0	367	12722.8	799	2.17806	1096	24.068	79	2479.0	195	0.5310	37
463	20324.7	367	12802.7	805	2.18902	1104	24.147	79	2498.5	197	0.5347	37
462	20361.4	367	12883.2	811	2.20006	1110	24.226	80	2518.2	198	0.5384	37
461	20398.1	369	12964.3	816	2.21116	1117	24.306	80	2538.0	200	0.5421	38
460	20435.0	369	13045.9	822	2.22233	1124	24.386	80	2558.0	202	0.5459	38
459	20471.9	370	13128.1	829	2.23357	1132	24.466	81	2578.2	204	0.5497	38
458	20508.9	371	13211.0	834	2.24489	1140	24.547	81	2598.6	206	0.5535	39
457	20546.0	371	13294.4	841	2.25629	1147	24.628	82	2619.2	208	0.5574	39
456	20583.1	373	13378.5	848	2.26776	1155	24.710	82	2640.0	210	0.5613	40
455	20620.4	373	13463.3	853	2.27931	1163	24.792	82	2661.0	212	0.5653	39
454	20657.7	374	13548.6	859	2.29094	1171	24.874	82	2682.2	213	0.5692	40
453	20695.1	375	13634.5	866	2.30265	1178	24.956	83	2703.5	216	0.5732	41
452	20732.6	576	13721.1	872	2.31443	1185	25.039	83	2725.1	218	0.5773	41
451	20770.2	377	13808.3	878	2.32628	1193	25.122	84	2746.9	219	0.5814	41
450	20807.9	377	13896.1	885	2.33821	1201	25.206	84	2768.8	222	0.5855	41
449	20845.6	378	13984.6	891	2.35022	1210	25.290	84	2791.0	224	0.5896	42
448	20883.4	380	14073.7	898	2.36232	1218	25.374	85	2813.4	226	0.5938	43
447	20921.4	380	14163.5	905	2.37450	1226	25.459	85	2836.0	228	0.5981	42
446	20959.4	380	14254.0	911	2.38676	1235	25.544	85	2858.8	231	0.6023	43
445	20997.4	382	14345.1	919	2.39911	1243	25.629	86	2881.9	232	0.6066	44
444	21035.6	383	14437.0	925	2.41154	1251	25.715	86	2905.1	235	0.6110	44
443	21073.9	383	14529.5	932	2.42405	1260	25.801	87	2928.6	237	0.6154	44
442	21112.2	385	14622.7	939	2.43665	1268	25.888	87	2952.3	239	0.6198	45
441	21150.7	385	14716.6	946	2.44933	1276	25.975	87	2976.2	241	0.6243	45
440	21189.2	386	14811.2	953	2.46209	1285	26.062	88	3000.3	243	0.6288	45
439	21227.8	387	14906.5	960	2.47494	1294	26.150	88	3024.6	246	0.6333	46
438	21266.5	388	15002.5	968	2.48788	1303	26.238	89	3049.2	249	0.6379	46
437	21305.3	389	15099.3	975	2.50091	1313	26.327	89	3074.1	250	0.6425	47
436	21344.2	389	15196.8	982	2.51404	1322	26.416	89	3099.1	253	0.6472	47

Digitized by Google

TABLE I—CONTINUED.

u.	$S(u)$.	Diff.	$A(u)$.	Diff.	$I(u)$.	Diff.	$T(u)$.	Diff.	$B(u)$.	Diff.	$M(u)$.	Diff.
435	21383.1	391	15295.0	990	2.52726	1331	26.505	90	3124.4	256	0.6519	48
434	21422.2	392	15394.0	997	2.54057	1340	26.595	90	3150.0	258	0.6567	48
433	21461.4	392	15493.7	1005	2.55397	1349	26.685	91	3175.8	261	0.6615	48
432	21500.6	394	15594.2	1012	2.56746	1358	26.776	91	3201.9	263	0.6663	49
431	21540.0	394	15695.4	1019	2.58104	1367	26.867	92	3228.2	265	0.6712	50
430	21579.4	395	15797.3	1027	2.59471	1377	26.959	92	3254.7	268	0.6762	50
429	21618.9	396	15900.0	1035	2.60846	1387	27.051	92	3281.5	271	0.6812	50
428	21658.5	397	16003.5	1044	2.62235	1397	27.143	93	3308.6	273	0.6862	51
427	21698.2	398	16107.9	1052	2.63632	1407	27.236	93	3335.9	277	0.6913	52
426	21738.0	399	16213.1	1060	2.65039	1417	27.329	94	3363.6	279	0.6965	52
425	21777.9	399	16319.1	1068	2.66456	1427	27.423	94	3391.5	281	0.7017	52
424	21817.8	401	16425.9	1076	2.67883	1437	27.517	95	3419.6	285	0.7069	53
423	21857.9	402	16533.5	1084	2.69320	1447	27.612	95	3448.1	287	0.7122	53
422	21898.1	403	16641.9	1093	2.70767	1458	27.707	96	3476.8	290	0.7175	54
421	21938.4	403	16751.2	1101	2.72225	1467	27.803	96	3505.8	292	0.7229	54
420	21978.7	404	16861.3	1109	2.73692	1477	27.899	96	3535.0	296	0.7283	55
419	22019.1	405	16972.2	1119	2.75169	1489	27.995	97	3564.6	298	0.7338	55
418	22059.6	406	17084.1	1127	2.76658	1500	28.092	97	3594.4	302	0.7393	56
417	22100.2	407	17196.8	1137	2.78158	1510	28.189	98	3624.6	305	0.7449	56
416	22140.9	409	17310.5	1145	2.79668	1522	28.287	98	3655.1	307	0.7505	57
415	22181.8	409	17425.0	1155	2.81190	1533	28.385	99	3685.8	311	0.7562	57
414	22222.7	410	17540.5	1163	2.82723	1544	28.484	99	3716.9	314	0.7619	58
413	22263.7	411	17656.8	1173	2.84267	1555	28.583	100	3748.3	317	0.7677	59
412	22304.8	413	17774.1	1181	2.85822	1566	28.683	100	3780.0	320	0.7736	59
411	22346.1	413	17892.2	1191	2.87388	1577	28.783	101	3812.0	323	0.7795	60
410	22387.4	414	18011.3	1200	2.88965	1589	28.884	101	3844.3	326	0.7855	60
409	22428.8	416	18131.3	1211	2.90554	1601	28.985	102	3876.9	330	0.7915	61
408	22470.4	416	18252.4	1220	2.92155	1613	29.087	102	3909.9	334	0.7976	61
407	22512.0	417	18374.4	1230	2.93768	1625	29.189	103	3943.3	337	0.8037	62
406	22553.7	419	18497.4	1240	2.95393	1637	29.292	103	3977.0	340	0.8099	63
405	22595.6	419	18621.4	1250	2.97030	1649	29.395	104	4011.0	344	0.8162	64
404	22637.5	421	18746.4	1259	2.98679	1662	29.499	104	4045.4	347	0.8226	64
403	22679.6	422	18872.3	1270	3.00341	1674	29.603	105	4080.1	351	0.8290	65
402	22721.8	422	18999.3	1280	3.02015	1686	29.708	105	4115.2	354	0.8355	65
401	22764.0	424	19127.3	1289	3.03701	1698	29.813	106	4150.6	358	0.8420	66
400	22806.4	424	19256.2	1300	3.05399	1710	29.919	106	4186.4	361	0.8486	66

Digitized by Google

TABLE I—CONTINUED.—*Auxiliary A.*

z.	1200.	Δ_z.	Δ_v.	1250.	Δ_z.	Δ_v.	1300.	Δ_z.	Δ_v.	1350.	Δ_z.	Δ_v.	1400.	Δ_z.	Δ_v.
400	0.0092	24	7	0.0085	23	6	0.0079	21	6	0.0073	20	5	0.0068	18	5
500	0.0116	24	8	0.0108	22	8	0.0100	21	7	0.0093	19	7	0.0086	18	6
600	0.0140	25	10	0.0130	23	9	0.0121	21	9	0.0112	20	8	0.0104	19	7
700	0.0165	26	12	0.0153	24	11	0.0142	22	10	0.0132	20	9	0.0123	19	8
800	0.0191	26	14	0.0177	24	13	0.0164	22	12	0.0152	21	10	0.0142	19	9
900	0.0217	26	16	0.0201	24	15	0.0186	23	13	0.0173	21	12	0.0161	20	11
1000	0.0243	27	18	0.0225	25	16	0.0209	23	15	0.0194	22	13	0.0181	20	12
1100	0.0270	27	20	0.0250	25	18	0.0232	23	16	0.0216	23	15	0.0201	20	14
1200	0.0297	27	22	0.0275	26	20	0.0255	24	18	0.0237	23	16	0.0221	21	15
1300	0.0324	28	23	0.0301	26	22	0.0279	24	19	0.0260	22	18	0.0242	21	17
1400	0.0352	28	25	0.0327	26	24	0.0303	24	21	0.0282	23	19	0.0263	22	19
1500	0.0380	28	27	0.0353	27	26	0.0327	25	22	0.0305	23	20	0.0285	22	20
1600	0.0408	28	28	0.0380	27	28	0.0352	26	24	0.0328	24	21	0.0307	22	21
1700	0.0436	29	29	0.0407	27	29	0.0378	26	26	0.0352	25	24	0.0329	23	22
1800	0.0465	30	31	0.0434	28	30	0.0404	26	27	0.0377	25	25	0.0352	23	24
1900	0.0495	30	33	0.0462	28	32	0.0430	27	28	0.0402	25	27	0.0375	23	25
2000	0.0525	30	35	0.0490	28	33	0.0457	27	30	0.0427	25	29	0.0398	24	26
2100	0.0555	31	37	0.0518	29	34	0.0484	27	32	0.0452	26	30	0.0422	24	27
2200	0.0586	31	39	0.0547	29	36	0.0511	27	33	0.0478	26	32	0.0446	25	28
2300	0.0617	31	41	0.0576	30	38	0.0538	28	34	0.0504	27	33	0.0471	26	30
2400	0.0648	32	42	0.0606	30	40	0.0566	29	35	0.0531	27	34	0.0497	25	32
2500	0.0680	32	44	0.0636	30	41	0.0595	28	37	0.0558	27	36	0.0522	26	33
2600	0.0712	32	46	0.0666	31	43	0.0623	29	38	0.0585	27	37	0.0548	26	34
2700	0.0744	33	47	0.0697	31	45	0.0652	30	40	0.0612	28	38	0.0574	26	36
2800	0.0777	33	49	0.0728	32	46	0.0682	30	42	0.0640	29	40	0.0600	27	37
2900	0.0810	33	50	0.0760	31	48	0.0712	30	43	0.0669	29	42	0.0627	28	38
3000	0.0843	33	52	0.0791	32	49	0.0742	30	44	0.0698	29	43	0.0655	28	40
3100	0.0876	34	53	0.0823	32	51	0.0772	31	45	0.0727	29	44	0.0683	28	41
3200	0.0910	34	55	0.0855	33	52	0.0803	32	47	0.0756	30	45	0.0711	28	43
3300	0.0944	35	56	0.0888	33	53	0.0835	32	49	0.0786	30	47	0.0739	29	44
3400	0.0979	35	58	0.0921	34	56	0.0867	33	51	0.0816	31	48	0.0768	29	45
3500	0.1014	35	59	0.0955	34	56	0.0900	32	53	0.0847	31	51	0.0797	29	47
3600	0.1049	36	60	0.0989	34	57	0.0932	32	54	0.0878	31	52	0.0826	30	48

Digitized by Google

TABLE I—CONTINUED.—*Auxiliary A.*

s.	1450.	Δ_s.	Δ_v.	1500.	Δ_s.	Δ_v.	1550.	Δ_s.	Δ_v.	1600.	Δ_s.	Δ_v.	1650.	Δ_s.	Δ_v.
400	0.0063	17	3	0.0060	15	4	0.0056	14	4	0.0052	14	3	0.0049	13	3
500	0.0080	17	5	0.0075	16	5	0.0070	14	4	0.0066	14	4	0.0062	13	4
600	0.0097	18	6	0.0091	16	6	0.0085	15	5	0.0080	14	5	0.0075	14	4
700	0.0115	18	8	0.0107	17	7	0.0100	16	6	0.0094	15	5	0.0089	14	5
800	0.0133	18	9	0.0124	17	8	0.0116	16	7	0.0109	15	6	0.0103	14	6
900	0.0151	18	10	0.0141	17	9	0.0132	16	8	0.0124	15	7	0.0117	14	7
1000	0.0169	18	11	0.0158	17	10	0.0148	16	9	0.0139	15	8	0.0131	14	8
1100	0.0187	19	12	0.0175	18	11	0.0164	17	10	0.0154	16	9	0.0145	15	9
1200	0.0206	19	13	0.0193	17	12	0.0181	17	11	0.0170	16	10	0.0160	14	10
1300	0.0225	19	15	0.0210	18	12	0.0198	17	12	0.0186	16	12	0.0174	16	10
1400	0.0244	21	16	0.0228	19	13	0.0215	17	13	0.0202	16	12	0.0190	16	11
1500	0.0265	21	18	0.0247	19	15	0.0232	17	14	0.0218	17	12	0.0206	16	12
1600	0.0286	21	20	0.0266	20	17	0.0249	19	14	0.0235	17	13	0.0222	16	13
1700	0.0307	21	21	0.0286	20	18	0.0268	19	16	0.0252	18	14	0.0238	16	14
1800	0.0328	22	22	0.0306	21	19	0.0287	20	17	0.0270	18	16	0.0254	17	15
1900	0.0350	22	23	0.0327	21	20	0.0307	19	19	0.0288	18	17	0.0271	17	16
2000	0.0372	23	24	0.0348	21	22	0.0326	20	20	0.0306	19	18	0.0288	18	17
2100	0.0395	23	26	0.0369	22	23	0.0346	21	21	0.0325	19	19	0.0306	18	18
2200	0.0418	23	27	0.0391	22	24	0.0367	20	23	0.0344	20	20	0.0324	18	19
2300	0.0441	24	28	0.0413	22	26	0.0387	21	23	0.0364	20	22	0.0342	19	20
2400	0.0465	24	30	0.0435	23	27	0.0408	22	24	0.0384	20	23	0.0361	19	21
2500	0.0489	25	31	0.0458	23	28	0.0430	22	26	0.0404	20	24	0.0380	19	22
2600	0.0514	24	33	0.0481	23	29	0.0452	22	28	0.0424	21	25	0.0399	20	23
2700	0.0538	25	34	0.0504	24	30	0.0474	22	29	0.0445	21	26	0.0419	20	24
2800	0.0563	26	35	0.0528	24	32	0.0496	23	30	0.0466	22	27	0.0439	21	25
2900	0.0589	26	37	0.0552	25	33	0.0519	23	31	0.0488	22	28	0.0460	21	26
3000	0.0615	27	38	0.0577	25	35	0.0542	24	33	0.0510	22	29	0.0481	21	27
3100	0.0642	26	40	0.0602	25	36	0.0566	24	34	0.0532	23	30	0.0502	22	28
3200	0.0668	27	41	0.0627	26	37	0.0590	25	35	0.0555	23	31	0.0524	22	30
3300	0.0695	28	42	0.0653	26	38	0.0615	24	37	0.0578	23	32	0.0546	22	31
3400	0.0723	27	44	0.0679	26	40	0.0639	25	38	0.0601	24	33	0.0568	22	32
3500	0.0750	28	45	0.0705	27	41	0.0664	25	39	0.0625	24	35	0.0590	23	33
3600	0.0778	28	46	0.0732	27	43	0.0689	26	40	0.0649	23	36	0.0613	23	34

Digitized by Google

TABLE I—CONTINUED.—*Auxiliary A.*

z.	1700.	Δ_z.	Δ_v.	1750.	Δ_z.	Δ_v.	1800.	Δ_z.	Δ_v.	1850.	Δ_z.	Δ_v.	1900.	Δ_z.	Δ_v.
400	0.0046	12	3	0.0043	12	2	0.0041	11	2	0.0039	10	2	0.0037	10	2
500	0.0058	13	3	0.0055	12	3	0.0052	11	3	0.0049	11	2	0.0047	10	2
600	0.0071	13	4	0.0067	12	4	0.0063	11	3	0.0060	10	3	0.0057	10	3
700	0.0084	13	5	0.0079	12	5	0.0074	12	4	0.0070	11	3	0.0067	10	4
800	0.0097	13	6	0.0091	12	5	0.0086	11	5	0.0081	11	4	0.0077	10	4
900	0.0110	13	7	0.0103	12	6	0.0097	12	5	0.0092	11	5	0.0087	11	4
1000	0.0123	13	8	0.0115	13	6	0.0109	12	6	0.0103	12	5	0.0098	11	5
1100	0.0136	14	8	0.0128	14	7	0.0121	13	6	0.0115	12	6	0.0109	11	5
1200	0.0150	14	8	0.0142	13	8	0.0134	12	7	0.0127	12	7	0.0120	11	6
1300	0.0164	15	9	0.0155	14	9	0.0146	13	7	0.0139	12	8	0.0131	12	6
1400	0.0179	15	10	0.0169	13	10	0.0159	13	8	0.0151	12	8	0.0143	12	7
1500	0.0194	15	12	0.0182	14	10	0.0172	14	9	0.0163	13	8	0.0155	12	8
1600	0.0209	15	13	0.0196	15	10	0.0186	13	10	0.0176	13	9	0.0167	12	9
1700	0.0224	15	13	0.0211	14	12	0.0199	14	10	0.0189	13	10	0.0179	13	9
1800	0.0239	16	14	0.0225	15	12	0.0213	14	11	0.0202	13	10	0.0192	12	10
1900	0.0255	16	15	0.0240	16	13	0.0227	15	12	0.0215	14	11	0.0204	13	10
2000	0.0271	17	15	0.0256	16	14	0.0242	15	13	0.0229	14	12	0.0217	13	11
2100	0.0288	17	16	0.0272	16	15	0.0257	15	14	0.0243	15	13	0.0230	14	11
2200	0.0305	17	17	0.0288	16	16	0.0272	15	14	0.0258	14	14	0.0244	14	12
2300	0.0322	18	18	0.0304	17	17	0.0287	15	15	0.0272	15	14	0.0258	14	13
2400	0.0340	18	19	0.0321	17	18	0.0303	16	16	0.0287	15	15	0.0272	14	14
2500	0.0358	18	20	0.0338	17	19	0.0319	16	17	0.0302	15	16	0.0286	15	14
2600	0.0376	19	21	0.0355	18	20	0.0335	17	18	0.0317	16	16	0.0301	15	15
2700	0.0395	19	22	0.0373	18	21	0.0352	17	19	0.0333	16	17	0.0316	15	16
2800	0.0414	20	23	0.0391	18	22	0.0369	17	20	0.0349	17	18	0.0331	15	16
2900	0.0434	20	25	0.0409	18	23	0.0386	18	20	0.0366	17	19	0.0346	16	17
3000	0.0454	20	27	0.0427	19	23	0.0404	18	21	0.0383	17	20	0.0362	16	17
3100	0.0474	20	28	0.0446	20	24	0.0422	18	22	0.0400	17	22	0.0378	17	18
3200	0.0494	21	28	0.0466	20	26	0.0440	19	23	0.0417	18	22	0.0395	17	20
3300	0.0515	21	29	0.0486	20	27	0.0459	19	24	0.0435	18	23	0.0412	17	21
3400	0.0536	21	30	0.0506	20	28	0.0478	19	25	0.0453	18	24	0.0429	17	22
3500	0.0557	22	31	0.0526	21	29	0.0497	20	26	0.0471	18	25	0.0446	18	22
3600	0.0579	22	32	0.0547	21	30	0.0517	20	28	0.0489	19	25	0.0464	19	23

Digitized by Google

TABLE I—CONTINUED.—*Auxiliary A.*

z.	1950.	Δ_z.	Δ_v.	2000.	Δ_z.	Δ_v.	2050.	Δ_z.	Δ_v.	2100.	Δ_z.	Δ_v.	2150.	Δ_z.	Δ_v.
400	0.0035	10	1	0.0034	9	2	0.0032	8	2	0.0030	8	1	0.0029	7	1
500	0.0045	9	2	0.0043	8	3	0.0040	8	2	0.0038	8	2	0.0036	8	1
600	0.0054	9	3	0.0051	9	3	0.0048	9	2	0.0046	8	2	0.0044	7	2
700	0.0063	10	3	0.0060	10	3	0.0057	9	3	0.0054	9	3	0.0051	8	2
800	0.0073	10	3	0.0070	9	4	0.0066	9	3	0.0063	8	4	0.0059	9	2
900	0.0083	10	4	0.0079	10	4	0.0075	9	4	0.0071	9	3	0.0068	8	3
1000	0.0093	11	4	0.0089	10	5	0.0084	10	4	0.0080	9	4	0.0076	9	3
1100	0.0104	10	5	0.0099	10	5	0.0094	9	5	0.0089	9	4	0.0085	9	4
1200	0.0114	11	5	0.0109	10	6	0.0103	10	5	0.0098	9	4	0.0094	9	4
1300	0.0125	11	6	0.0119	10	6	0.0113	10	6	0.0107	10	4	0.0103	9	5
1400	0.0136	11	7	0.0129	11	6	0.0123	10	6	0.0117	10	5	0.0112	9	5
1500	0.0147	11	7	0.0140	11	7	0.0133	11	6	0.0127	10	6	0.0121	10	5
1600	0.0158	12	7	0.0151	11	7	0.0144	10	7	0.0137	10	6	0.0131	9	6
1700	0.0170	12	8	0.0162	11	8	0.0154	11	7	0.0147	10	7	0.0140	10	6
1800	0.0182	12	9	0.0173	11	8	0.0165	10	8	0.0157	10	7	0.0150	10	7
1900	0.0194	12	10	0.0184	12	9	0.0175	11	8	0.0167	11	7	0.0160	10	8
2000	0.0206	13	10	0.0196	12	10	0.0186	12	8	0.0178	11	8	0.0170	10	8
2100	0.0219	13	11	0.0208	12	10	0.0198	12	9	0.0189	11	9	0.0180	11	8
2200	0.0232	13	12	0.0220	13	10	0.0210	12	10	0.0200	11	9	0.0191	10	9
2300	0.0245	13	12	0.0233	13	11	0.0222	12	11	0.0211	12	10	0.0201	11	9
2400	0.0258	14	13	0.0246	12	12	0.0234	12	11	0.0223	11	11	0.0212	11	9
2500	0.0272	14	14	0.0258	13	12	0.0246	12	12	0.0234	12	11	0.0223	12	10
2600	0.0286	14	15	0.0271	14	13	0.0258	13	12	0.0246	12	11	0.0135	11	11
2700	0.0300	15	15	0.0285	14	14	0.0271	13	13	0.0258	13	12	0.0246	12	11
2800	0.0315	15	16	0.0299	14	15	0.0284	14	13	0.0271	13	13	0.0258	13	11
2900	0.0330	15	17	0.0313	14	15	0.0298	14	14	0.0284	13	13	0.0271	12	13
3000	0.0345	15	18	0.0327	14	15	0.0312	14	15	0.0297	13	14	0.0283	13	13
3100	0.0360	15	19	0.0341	15	15	0.0326	14	16	0.0310	14	14	0.0296	13	14
3200	0.0375	16	19	0.0356	16	16	0.0340	15	16	0.0324	14	15	0.0309	13	14
3300	0.0391	16	19	0.0372	16	17	0.0355	15	17	0.0338	14	16	0.0322	14	15
3400	0.0407	17	19	0.0388	15	18	0.0370	15	18	0.0352	14	16	0.0336	13	16
3500	0.0424	17	21	0.0403	16	18	0.0385	15	19	0.0366	15	17	0.0349	14	16
3600	0.0441	18	22	0.0419	17	19	0.0400	16	19	0.0381	15	18	0.0363	15	16

Digitized by Google

TABLE I—CONTINUED.—*Auxiliary A.*

s.	1200	Δ_s.	Δ_v.	1250.	Δ_s.	Δ_v.	1300.	Δ_s.	Δ_v.	1350.	Δ_s.	Δ_v.	1400.	Δ_s.	Δ_v.
3600	0.1049	36	60	0.0989	34	57	0.0932	34	54	0.0878	31	52	0.0826	30	48
3700	0.1085	36	62	0.1023	34	59	0.0964	33	55	0.0909	31	53	0.0856	30	50
3800	0.1121	36	64	0.1057	35	60	0.0997	33	57	0.0940	31	54	0.0886	30	51
3900	0.1157	37	65	0.1092	35	62	0.1030	34	59	0.0971	33	55	0.0916	31	52
4000	0.1194	38	67	0.1127	35	63	0.1064	34	60	0.1004	33	57	0.0947	32	53
4100	0.1232	38	70	0.1162	36	64	0.1098	34	61	0.1037	33	58	0.0979	32	55
4200	0.1270	37	72	0.1198	36	66	0.1132	34	62	0.1070	33	59	0.1011	32	57
4300	0.1307	38	73	0.1234	36	68	0.1166	35	63	0.1103	34	60	0.1043	32	58
4400	0.1345	39	75	0.1270	37	69	0.1201	35	64	0.1137	34	62	0.1075	33	59
4500	0.1384	39	77	0.1307	37	71	0.1236	36	65	0.1171	34	63	0.1108	33	61
4600	0.1423	39	79	0.1344	38	72	0.1272	36	67	0.1205	35	64	0.1141	33	62
4700	0.1462	39	80	0.1382	38	74	0.1308	37	68	0.1240	35	66	0.1174	34	63
4800	0.1501	40	81	0.1420	38	75	0.1345	37	70	0.1275	35	67	0.1208	34	65
4900	0.1541	40	83	0.1458	39	76	0.1382	37	72	0.1310	36	68	0.1242	34	66
5000	0.1581	41	84	0.1497	39	78	0.1419	37	73	0.1346	36	70	0.1276	34	67
5100	0.1622	42	86	0.1536	40	80	0.1456	38	74	0.1382	36	72	0.1310	35	68
5200	0.1664	41	88	0.1576	40	82	0.1494	38	76	0.1418	37	73	0.1345	36	69
5300	0.1705	42	89	0.1616	40	84	0.1532	39	77	0.1455	37	74	0.1381	36	71
5400	0.1747	42	91	0.1656	40	85	0.1571	39	79	0.1492	38	75	0.1417	36	72
5500	0.1789	43	93	0.1696	41	86	0.1610	39	80	0.1530	38	77	0.1453	37	73
5600	0.1832	43	95	0.1737	41	88	0.1649	40	81	0.1568	38	78	0.1490	37	75
5700	0.1875	44	97	0.1778	42	89	0.1689	40	83	0.1606	39	79	0.1527	37	77
5800	0.1919	44	99	0.1820	42	91	0.1729	41	84	0.1645	39	81	0.1564	38	78
5900	0.1963	45	101	0.1862	43	92	0.1770	41	86	0.1684	40	82	0.1602	38	80
6000	0.2008	44	103	0.1905	43	94	0.1811	41	87	0.1724	40	84	0.1640	38	81
6100	0.2052	44	104	0.1948	43	96	0.1852	42	88	0.1764	40	86	0.1678	39	82
6200	0 2096	45	105	0.1991	43	97	0.1894	42	90	0.1804	40	87	0.1717	39	84
6300	0.2141	46	107	0.2034	44	98	0.1936	43	92	0.1844	41	88	0.1756	39	85
6400	0.2187	47	109	0.2078	44	99	0.1979	42	94	0.1885	41	90	0.1795	40	86
6500	0.2234	47	112	0.2122	45	101	0.2021	42	95	0.1926	41	91	0.1835	40	88
6600	0.2281	46	114	0.2167	45	104	0.2063	44	96	0.1967	42	92	0.1875	40	89
6700	0.2327	47	115	0.2212	46	105	0.2107	45	98	0.2009	43	94	0.1915	41	90
6800	0.2374	48	116	0.2258	47	106	0.2152	45	100	0.2052	43	96	0.1956	42	91

Digitized by Google

TABLE I—CONTINUED.—*Auxiliary A.*

z.	1450.	Δ_s.	Δ_v.	1500.	Δ_s.	Δ_v.	1550.	Δ_s.	Δ_v.	1600.	Δ_s.	Δ_v.	1650.	Δ_s.	Δ_v.
3600	0.0778	28	46	0.0732	27	43	0.0689	26	40	0.0649	25	36	0.0613	23	34
3700	0.0806	29	47	0.0759	28	44	0.0715	27	41	0.0674	25	38	0.0636	24	35
3800	0.0835	29	48	0.0787	28	45	0.0742	27	43	0.0699	26	39	0.0660	24	37
3900	0.0864	30	49	0.0815	28	46	0.0769	27	44	0.0725	26	41	0.0684	25	38
4000	0.0894	30	51	0.0843	29	47	0.0796	27	45	0.0751	26	42	0.0709	25	39
4100	0.0924	30	52	0.0872	29	49	0.0823	28	46	0.0777	27	43	0.0734	26	40
4200	0.0954	31	53	0.0901	29	50	0.0851	28	47	0.0804	27	44	0.0760	26	41
4300	0.0985	31	54	0.0930	30	51	0.0879	28	48	0.0831	27	45	0.0786	26	42
4400	0.1016	31	56	0.0960	30	53	0.0907	29	49	0.0858	28	46	0.0812	26	43
4500	0.1047	32	57	0.0990	30	54	0.0936	29	50	0.0886	28	48	0.0838	27	44
4600	0.1079	32	59	0.1020	31	55	0.0965	30	51	0.0914	28	49	0.0865	27	45
4700	0.1111	32	60	0.1051	31	56	0.0995	30	52	0.0942	29	50	0.0892	28	46
4800	0.1143	33	61	0.1082	31	57	0.1025	30	53	0.0971	29	51	0.0920	28	48
4900	0.1176	33	63	0.1113	32	58	0.1055	31	55	0.1000	29	52	0.0948	28	49
5000	0.1209	33	64	0.1145	32	59	0.1086	31	57	0.1029	30	53	0.0976	28	50
5100	0.1242	34	65	0.1177	33	60	0.1117	31	58	0.1059	30	55	0.1004	29	51
5200	0.1276	34	66	0.1210	33	62	0.1148	31	59	0.1089	30	56	0.1033	29	52
5300	0.1310	35	67	0.1243	33	64	0.1179	32	60	0.1119	31	57	0.1062	30	53
5400	0.1345	35	69	0.1276	34	65	0.1211	32	61	0.1150	31	58	0.1092	30	55
5500	0.1380	35	70	0.1310	34	67	0.1243	33	62	0.1181	32	59	0.1122	30	56
5600	0.1415	35	71	0.1344	34	68	0.1276	33	63	0.1213	32	61	0.1152	31	57
5700	0.1450	36	72	0.1378	34	69	0.1309	34	64	0.1245	32	62	0.1183	31	58
5800	0.1486	36	74	0.1412	35	69	0.1343	34	66	0.1277	32	63	0.1214	31	59
5900	0.1522	37	75	0.1447	35	70	0.1377	34	68	0.1309	33	64	0.1245	32	60
6000	0.1559	37	77	0.1482	36	71	0.1411	34	69	0.1342	33	65	0.1277	32	61
6100	0.1596	37	78	0.1518	36	73	0.1445	35	70	0.1375	34	66	0.1309	33	62
6200	0.1633	38	79	0.1554	37	74	0.1480	35	71	0.1409	34	67	0.1342	33	64
6300	0.1671	38	80	0.1591	37	76	0.1515	36	72	0.1443	34	68	0.1375	33	65
6400	0.1709	38	81	0.1628	37	77	0.1551	36	74	0.1477	35	69	0.1408	33	66
6500	0.1747	39	82	0.1665	37	78	0.1587	36	75	0.1512	35	71	0.1441	34	66
6600	0.1786	39	84	0.1702	38	79	0.1623	36	76	0.1547	36	72	0.1475	34	67
6700	0.1825	40	85	0.1740	39	81	0.1659	37	76	0.1583	36	74	0.1509	35	69
6800	0.1865	40	86	0.1779	38	83	0.1696	37	77	0.1619	35	75	0.1544	35	70

Digitized by Google

TABLE I—CONTINUED.—*Auxiliary A.*

z.	1700.	Δ_z.	Δ_v.	1750.	Δ_z.	Δ_v.	1800.	Δ_z.	Δ_v.	1850.	Δ_z.	Δ_v.	1900.	Δ_z.	Δ_v.
3600	0.0579	22	32	0.0547	21	30	0.0517	20	28	0.0489	19	25	0.0464	18	23
3700	0.0601	22	33	0.0568	22	31	0.0537	21	29	0.0508	20	26	0.0482	19	25
3800	0.0623	23	33	0.0590	22	32	0.0558	21	30	0.0528	20	27	0.0501	19	25
3900	0.0646	24	34	0.0612	22	33	0.0579	21	31	0.0548	20	28	0.0520	20	26
4000	0.0670	24	36	0.0634	23	34	0.0600	22	32	0.0568	21	28	0.0540	19	27
4100	0.0694	25	37	0.0657	23	35	0.0622	22	33	0.0589	21	30	0.0559	20	27
4200	0.0719	25	39	0.0680	23	36	0.0644	22	34	0.0610	22	31	0.0579	21	28
4300	0.0744	25	41	0.0703	24	37	0.0666	23	34	0.0632	22	32	0.0600	21	30
4400	0.0769	25	42	0.0727	24	38	0.0689	22	35	0.0654	22	33	0.0621	21	31
4500	0.0794	26	43	0.0751	25	40	0.0711	23	35	0.0676	22	34	0.0642	21	32
4600	0.0820	26	44	0.0776	25	42	0.0734	25	36	0.0698	23	35	0.0663	22	32
4700	0.0846	26	45	0.0801	25	42	0.0759	25	38	0.0721	23	36	0.0685	22	33
4800	0.0872	27	46	0.0826	26	42	0.0784	25	40	0.0744	23	37	0.0707	23	34
4900	0.0899	27	47	0.0852	26	43	0.0809	25	42	0.0767	24	37	0.0730	23	35
5000	0.0926	27	48	0.0878	26	44	0.0834	25	43	0.0791	25	38	0.0753	23	36
5100	0.0953	28	49	0.0904	27	45	0.0859	25	43	0.0816	25	40	0.0776	24	37
5200	0.0981	28	50	0.0931	27	47	0.0884	26	43	0.0841	25	41	0.0800	24	39
5300	0.1009	28	51	0.0958	28	48	0.0910	27	44	0.0866	25	42	0.0824	25	40
5400	0.1037	29	51	0.0986	28	49	0.0937	27	46	0.0891	26	42	0.0849	25	41
5500	0.1066	29	52	0.1014	28	50	0.0964	27	47	0.0917	26	43	0.0874	25	42
5600	0.1095	30	53	0.1042	28	51	0.0991	27	48	0.0943	27	44	0.0899	25	43
5700	0.1125	30	55	0.1070	29	52	0.1018	28	48	0.0970	27	46	0.0924	26	43
5800	0.1155	30	56	0.1099	29	53	0.1046	28	49	0.0997	27	47	0.0950	26	44
5900	0.1185	31	57	0.1128	30	54	0.1074	29	50	0.1024	27	48	0.0976	27	45
6000	0.1216	31	58	0.1158	30	55	0.1103	29	52	0.1051	28	48	0.1003	26	46
6100	0.1247	31	59	0.1188	30	56	0.1132	29	53	0.1079	28	50	0.1029	27	47
6200	0.1278	32	60	0.1218	31	57	0.1161	30	54	0.1107	29	51	0.1056	28	48
6300	0.1310	32	61	0.1249	31	58	0.1191	30	55	0.1136	29	52	0.1084	28	49
6400	0.1342	33	62	0.1280	31	59	0.1221	30	56	0.1165	29	53	0.1112	28	50
6500	0.1375	33	64	0.1311	31	60	0.1251	31	57	0.1194	30	54	0.1140	29	50
6600	0.1408	32	66	0.1342	32	60	0.1282	31	58	0.1224	30	55	0.1169	29	51
6700	0.1440	33	66	0.1374	33	61	0.1313	31	59	0.1254	30	56	0.1198	29	52
6800	0.1473	34	66	0.1407	32	63	0.1344	31	60	0.1284	31	57	0.1227	30	53

Digitized by Google

TABLE I—CONTINUED.—*Auxiliary A.*

s.	1950.	Δ_s.	Δ_v.	2000.	Δ_s.	Δ_v.	2050.	Δ_s.	Δ_v.	2100.	Δ_s.	Δ_v.	2150.	Δ_s.	Δ_v.
3600	0.0441	18	22	0.0419	17	20	0.0399	16	18	0.0381	15	18	0.0363	15	16
3700	0.0459	17	23	0.0436	17	21	0.0415	16	19	0.0396	15	18	0.0378	14	18
3800	0.0476	18	23	0.0453	17	22	0.0431	16	20	0.0411	15	19	0.0392	15	18
3900	0.0494	19	24	0.0470	18	23	0.0447	17	21	0.0426	16	19	0.0407	15	19
4000	0.0513	19	25	0.0488	18	24	0.0464	17	22	0.0442	16	20	0.0422	16	19
4100	0.0532	19	26	0.0506	18	25	0.0481	18	23	0.0458	17	20	0.0438	16	20
4200	0.0551	19	27	0.0524	18	26	0.0499	17	24	0.0475	17	21	0.0454	16	21
4300	0.0570	20	28	0.0542	19	26	0.0516	18	24	0.0492	17	22	0.0470	16	22
4400	0.0590	20	28	0.0561	19	27	0.0534	19	25	0.0509	18	23	0.0486	17	22
4500	0.0610	21	30	0.0580	20	27	0.0553	19	26	0.0527	18	24	0.0503	17	23
4600	0.0631	21	31	0.0600	20	28	0.0572	19	27	0.0545	18	25	0.0520	18	24
4700	0.0652	21	32	0.0620	20	29	0.0591	19	28	0.0563	19	25	0.0538	18	25
4800	0.0673	22	33	0.0640	21	30	0.0610	20	28	0.0582	19	26	0.0556	18	26
4900	0.0695	22	34	0.0661	21	31	0.0630	20	29	0.0601	19	27	0.0574	19	27
5000	0.0717	22	35	0.0682	21	32	0.0650	21	30	0.0620	20	27	0.0593	19	28
5100	0.0739	22	36	0.0703	22	32	0.0671	21	31	0.0640	20	28	0.0612	19	29
5200	0.0761	23	36	0.0725	22	33	0.0692	21	32	0.0660	20	29	0.0631	19	29
5300	0.0784	24	37	0.0747	23	34	0.0713	22	33	0.0680	20	30	0.0650	20	29
5400	0.0808	24	38	0.0770	23	35	0.0735	22	34	0.0701	21	31	0.0670	20	30
5500	0.0832	24	39	0.0793	23	36	0.0757	22	35	0.0722	21	32	0.0690	21	30
5600	0.0856	25	40	0.0816	24	37	0.0779	23	35	0.0744	22	33	0.0711	22	31
5700	0.0881	25	41	0.0840	24	38	0.0802	23	36	0.0766	22	33	0.0733	21	33
5800	0.0906	25	42	0.0864	24	39	0.0825	24	37	0.0788	22	34	0.0754	21	33
5900	0.0931	26	43	0.0888	25	39	0.0849	24	39	0.0810	23	35	0.0775	22	33
6000	0.0957	25	44	0.0913	25	40	0.0873	24	40	0.0833	24	36	0 0797	23	34
6100	0.0982	26	45	0.0938	25	41	0.0897	24	40	0.0857	24	37	0.0820	23	36
6200	0.1008	27	45	0.0963	26	42	0.0921	25	40	0.0881	24	38	0.0843	23	37
6300	0.1035	27	46	0.0989	26	43	0.0946	25	41	0.0905	24	39	0.0866	23	38
6400	0.1062	28	47	0.1015	26	44	0.0971	25	42	0.0929	24	40	0.0889	23	38
6500	0.1090	28	49	0.1041	27	45	0.0996	26	43	0.0953	25	41	0.0912	24	38
6600	0.1118	28	50	0.1068	27	47	0.1022	26	44	0.0978	25	42	0.0936	25	38
6700	0.1146	28	51	0.1095	28	47	0.1048	27	45	0.1003	26	42	0.0961	26	40
6800	0.1174	29	51	0.1123	28	48	0.1075	27	46	0.1029	26	42	0.0987	25	42

Digitized by Google

TABLE I—CONTINUED.—*Auxiliary B.*

z.	1200.	Δ_z.	Δ_v.	1250.	Δ_z.	Δ_v.	1300.	Δ_z.	Δ_v.	1350.	Δ_z.	Δ_v.	1400.	Δ_z.	Δ_v.
400	0.0096	26	7	0.0089	23	7	0.0082	22	6	0.0076	21	5	0.0071	20	5
500	0.0122	27	10	0.0112	25	8	0.0104	23	7	0.0097	22	6	0.0091	20	7
600	0.0149	27	12	0.0137	26	10	0.0127	24	8	0.0119	22	8	0.0111	21	8
700	0.0176	28	13	0.0163	26	12	0.0151	25	10	0.0141	23	9	0.0132	21	10
800	0.0204	29	15	0.0189	27	13	0.0176	26	12	0.0164	24	11	0.0153	22	10
900	0.0233	30	17	0.0216	28	14	0.0202	26	14	0.0188	25	13	0.0175	24	12
1000	0.0263	31	19	0.0244	30	16	0.0228	28	15	0.0213	26	14	0.0199	24	13
1100	0.0294	31	20	0.0274	30	18	0.0256	29	17	0.0239	27	16	0.0223	24	15
1200	0.0325	32	21	0.0304	30	19	0.0285	28	19	0.0266	27	19	0.0247	26	16
1300	0.0357	33	23	0.0334	31	21	0.0313	29	20	0.0293	27	20	0.0273	26	17
1400	0.0390	34	25	0.0365	32	23	0.0342	31	22	0.0320	29	21	0.0299	27	18
1500	0.0424	34	27	0.0397	33	24	0.0373	31	24	0.0349	30	23	0.0326	28	20
1600	0.0458	35	28	0.0430	33	26	0.0404	32	25	0.0379	30	25	0.0354	29	21
1700	0.0493	36	30	0.0463	34	27	0.0436	32	27	0.0409	31	26	0.0383	30	23
1800	0.0529	36	32	0.0497	35	29	0.0468	33	28	0.0440	32	27	0.0413	30	25
1900	0.0565	36	33	0.0532	35	31	0.0501	34	29	0.0472	32	29	0.0443	31	26
2000	0.0601	37	34	0.0567	36	32	0.0535	35	31	0.0504	34	30	0.0474	33	28
2100	0.0638	38	35	0.0603	37	33	0.0570	35	32	0.0538	34	31	0.0507	33	30
2200	0.0676	39	36	0.0640	37	35	0.0605	36	33	0.0572	35	32	0.0540	33	31
2300	0.0715	39	38	0.0677	38	36	0.0641	37	34	0.0607	35	34	0.0573	34	32
2400	0.0754	40	39	0.0715	38	37	0.0678	37	36	0.0642	36	35	0.0607	35	34
2500	0.0794	40	41	0.0753	39	38	0.0715	38	37	0.0678	37	36	0.0642	35	35
2600	0.0834	41	42	0.0792	40	39	0.0753	38	38	0.0715	37	38	0.0677	36	36
2700	0.0875	42	43	0.0832	40	41	0.0791	39	39	0.0752	38	39	0.0713	37	37
2800	0.0917	43	45	0.0872	41	42	0.0830	40	40	0.0790	39	40	0.0750	38	39
2900	0.0960	43	47	0.0913	42	43	0.0870	40	41	0.0829	39	41	0.0788	38	40
3000	0.1003	44	48	0.0955	43	45	0.0910	41	42	0.0868	40	42	0.0826	39	41
3100	0.1047	45	49	0.0998	43	47	0.0951	42	43	0.0908	40	43	0.0865	39	42
3200	0.1092	46	51	0.1041	44	48	0.0993	42	45	0.0948	41	44	0.0904	40	43
3300	0.1138	46	53	0.1085	44	50	0.1035	43	46	0.0989	42	45	0.0944	40	44
3400	0.1184	47	55	0.1129	46	51	0.1078	44	47	0.1031	42	47	0.0984	41	45
3500	0.1231	48	56	0.1175	47	53	0.1122	45	49	0.1073	43	48	0.1025	42	46
3600	0.1279	49	57	0.1222	47	55	0.1167	45	51	0.1116	44	49	0.1067	43	47

Digitized by Google

TABLE I—CONTINUED.—*Auxiliary B.*

s.	1450.	Δ_s.	Δ_v.	1500.	Δ_s.	Δ_v.	1550.	Δ_s.	Δ_v.	1600.	Δ_s.	Δ_v.	1650.	Δ_s.	Δ_v.
400	0.0066	18	5	0.0061	17	4	0.0057	16	3	0.0054	15	3	0.0051	14	3
500	0.0084	19	6	0.0078	18	5	0.0073	17	4	0.0069	15	4	0.0065	14	4
600	0.0103	19	7	0.0096	18	6	0.0090	17	6	0.0084	16	5	0.0079	15	4
700	0.0122	19	8	0.0114	19	7	0.0107	18	7	0.0100	17	6	0.0094	16	5
800	0.0141	22	10	0.0133	20	8	0.0125	18	8	0.0117	17	7	0.0110	16	7
900	0.0163	23	12	0.0153	20	10	0.0143	19	9	0.0134	18	8	0.0126	17	7
1000	0.0186	22	13	0.0173	21	11	0.0162	20	10	0.0152	19	9	0.0143	17	8
1100	0.0208	23	14	0.0194	22	12	0.0182	20	11	0.0171	19	11	0.0160	18	9
1200	0.0231	25	15	0.0216	23	14	0.0202	22	12	0.0190	20	12	0.0178	19	10
1300	0.0256	25	17	0.0239	24	15	0.0224	22	14	0.0210	20	13	0.0197	19	11
1400	0.0281	25	18	0.0263	24	17	0.0246	23	16	0.0230	22	14	0.0216	20	12
1500	0.0306	27	19	0.0287	25	18	0.0269	24	17	0.0252	22	16	0.0236	21	13
1600	0.0333	27	21	0.0312	26	19	0.0293	24	19	0.0274	23	17	0.0257	22	15
1700	0.0360	28	22	0.0338	26	21	0.0317	24	20	0.0297	23	18	0.0279	22	16
1800	0.0388	29	24	0.0364	27	23	0.0341	26	21	0.0320	25	19	0.0301	23	17
1900	0.0417	29	26	0.0391	28	24	0.0367	27	22	0.0345	25	21	0.0324	24	18
2000	0.0446	31	27	0.0419	29	25	0.0394	27	24	0.0370	26	22	0.0348	25	20
2100	0.0477	32	29	0.0448	30	27	0.0421	28	25	0.0396	27	23	0.0373	25	22
2200	0.0509	32	31	0.0478	31	29	0.0449	29	26	0.0423	28	25	0.0398	27	23
2300	0.0541	32	32	0.0509	31	31	0.0478	30	27	0.0451	28	26	0.0425	27	25
2400	0.0573	34	33	0.0540	32	32	0.0508	31	29	0.0479	29	27	0.0452	27	26
2500	0.0607	34	35	0.0572	33	33	0.0539	31	31	0.0508	30	29	0.0479	28	27
2600	0.0641	35	36	0.0605	34	35	0.0570	33	32	0.0538	31	31	0.0507	30	28
2700	0.0676	35	37	0.0639	34	36	0.0603	33	34	0.0569	32	32	0.0537	30	30
2800	0.0711	37	38	0.0673	35	37	0.0636	34	35	0.0601	33	34	0.0567	31	31
2900	0.0748	37	40	0.0708	36	38	0.0670	35	36	0.0634	33	36	0.0598	32	32
3000	0.0785	38	41	0.0744	37	39	0.0705	35	38	0.0667	34	37	0.0630	33	34
3100	0.0823	38	42	0.0781	37	41	0.0740	36	39	0.0701	35	38	0.0663	34	35
3200	0.0861	39	43	0.0818	38	42	0.0776	37	40	0.0736	36	39	0.0697	35	37
3300	0.0900	39	44	0.0856	38	43	0.0813	37	41	0.0772	36	40	0.0732	35	38
3400	0.0939	40	45	0.0894	39	44	0.0850	38	42	0.0808	37	41	0.0767	36	39
3500	0.0979	41	46	0.0933	40	45	0.0888	39	43	0.0845	38	42	0.0803	37	40
3600	0.1020	41	47	0.0973	40	46	0.0927	39	44	0.0883	38	43	0.0840	37	42

Digitized by Google

TABLE I—CONTINUED.—*Auxiliary B.*

z.	1700.	Δ_z.	Δ_v.	1750.	Δ_z.	Δ_v.	1800.	Δ_z.	Δ_v.	1850.	Δ_z.	Δ_v.	1900.	Δ_z.	Δ_v.
400	0.0048	13	3	0.0045	13	2	0.0043	12	2	0.0041	11	2	0.0039	10	2
500	0.0061	14	3	0.0058	13	3	0.0055	12	3	0.0052	11	3	0.0049	11	2
600	0.0075	14	4	0.0071	13	4	0.0067	12	4	0.0063	12	3	0.0060	11	3
700	0.0089	14	5	0.0084	13	5	0.0079	13	4	0.0075	12	4	0.0071	12	3
800	0.0103	16	6	0 0097	15	5	0.0092	14	5	0.0087	13	4	0.0083	12	4
900	0.0119	16	7	0.0112	15	6	0.0106	14	6	0.0100	14	5	0.0095	13	5
1000	0.0135	16	8	0.0127	16	7	0.0120	15	6	0.0114	14	6	0.0108	13	6
1100	0.0151	17	8	0.0143	16	8	0.0135	15	7	0.0128	14	7	0.0121	14	6
1200	0.0168	18	9	0.0159	17	9	0.0150	16	8	0.0142	15	7	0.0135	14	7
1300	0.0186	18	10	0.0176	17	10	0.0166	16	9	0.0157	15	8	0.0149	14	8
1400	0.0204	19	11	0.0193	17	11	0.0182	17	10	0.0172	16	9	0.0163	15	8
1500	0.0223	19	13	0.0210	18	11	0.0199	17	11	0.0188	17	10	0.0178	16	9
1600	0.0242	21	14	0.0228	20	12	0.0216	18	11	0.0205	17	11	0.0194	16	10
1700	0.0263	21	15	0.0248	20	14	0.0234	19	12	0.0222	17	12	0.0210	17	10
1800	0.0284	22	16	0.0268	21	15	0.0253	20	14	0.0239	19	12	0.0227	18	11
1900	0.0306	22	17	0.0289	21	16	0.0273	20	15	0.0258	19	13	0.0245	18	13
2000	0.0328	23	18	0.0310	21	17	0.0293	20	16	0.0277	19	14	0.0263	18	14
2100	0.0351	24	20	0.0331	23	18	0.0313	22	17	0.0296	21	15	0.0281	19	14
2200	0.0375	25	21	0.0354	24	19	0.0335	22	18	0.0317	21	17	0.0300	20	15
2300	0.0400	26	22	0.0378	24	21	0.0357	23	19	0.0338	22	18	0.0320	21	16
2400	0.0426	26	24	0.0402	25	22	0.0380	24	20	0.0360	23	19	0.0341	22	17
2500	0.0452	27	25	0.0427	26	23	0.0404	24	21	0.0383	23	20	0.0363	22	18
2600	0.0479	28	26	0.0453	26	25	0.0428	26	22	0.0406	24	21	0.0385	23	19
2700	0.0507	29	28	0.0479	28	25	0.0454	26	24	0.0430	25	22	0.0408	23	21
2800	0.0536	30	29	0.0507	29	27	0.0480	27	25	0.0455	25	24	0.0431	25	22
2900	0.0566	30	30	0.0536	29	29	0.0507	28	27	0.0480	27	25	0.0456	25	23
3000	0.0596	32	31	0.0565	30	30	0.0535	29	28	0.0507	27	26	0.0481	26	24
3100	0.0628	32	33	0.0595	31	31	0.0564	30	30	0.0534	29	27	0.0507	27	25
3200	0.0660	34	34	0.0626	32	32	0.0594	30	31	0.0563	29	29	0.0534	27	27
3300	0.0694	34	36	0.0658	32	34	0.0624	31	32	0.0592	29	30	0.0561	29	28
3400	0.0728	35	38	0.0690	34	35	0.0655	32	34	0.0621	31	31	0.0590	30	30
3500	0 0763	35	39	0.0724	34	37	0.0687	33	35	0.0652	32	32	0.0620	30	31
3600	0.0798	36	40	0.0758	34	38	0.0720	34	36	0.0684	32	34	0.0650	31	32

Digitized by Google

TABLE I—CONTINUED.—*Auxiliary B.*

z.	1950.	Δ_z.	Δ_v.	2000.	Δ_z.	Δ_v.	2050.	Δ_z.	Δ_v.	2100.	Δ_z.	Δ_v.	2150.	Δ_z.	Δ_v.
400	0.0037	10	1	0.0036	10	2	0.0034	9	2	0.0032	8	2	0.0030	8	2
500	0.0047	10	1	0.0046	10	3	0.0043	9	3	0.0040	9	2	0.0038	9	2
600	0.0057	11	1	0.0056	9	4	0.0052	9	3	0.0049	9	2	0.0047	8	2
700	0.0068	11	3	0.0065	10	4	0.0061	10	3	0.0058	10	3	0.0055	9	2
800	0.0079	11	4	0.0075	11	4	0.0071	10	3	0.0068	10	4	0.0064	10	2
900	0.0090	12	4	0.0086	11	5	0.0081	11	3	0.0078	10	4	0.0074	10	3
1000	0.0102	13	5	0.0097	12	5	0.0092	11	4	0.0088	11	4	0.0084	10	4
1100	0.0115	13	6	0.0109	12	5	0.0103	12	5	0.0099	11	5	0.0094	11	4
1200	0.0128	13	7	0.0121	13	6	0.0115	12	5	0.0110	12	5	0.0105	11	5
1300	0 0141	14	7	0.0134	13	7	0.0127	13	5	0.0122	12	6	0.0116	11	5
1400	0.0155	14	8	0.0147	14	7	0.0140	13	6	0.0134	12	7	0.0127	12	5
1500	0.0169	15	8	0.0161	14	8	0.0153	14	7	0.0146	13	7	0.0139	12	6
1600	0.0184	16	9	0.0175	15	8	0.0167	14	8	0.0159	13	8	0.0151	13	6
1700	0.0200	16	10	0.0190	15	9	0.0181	14	9	0.0172	14	8	0.0164	13	7
1800	0.0216	16	11	0.0205	16	10	0.0195	15	9	0.0186	14	9	0.0177	14	7
1900	0.0232	17	11	0.0221	16	11	0.0210	16	10	0.0200	15	9	0.0191	14	8
2000	0.0249	18	12	0.0237	17	11	0.0226	16	11	0.0215	15	10	0.0205	15	9
2100	0.0267	18	13	0.0254	17	12	0.0242	16	12	0.0230	16	10	0.0220	15	10
2200	0.0285	19	14	0.0271	18	13	0.0258	17	12	0.0246	16	11	0.0235	15	11
2300	0.0304	20	15	0.0289	19	14	0.0275	18	13	0.0262	17	12	0.0250	16	11
2400	0.0324	21	16	0.0308	20	15	0.0293	19	14	0.0279	18	13	0.0266	17	12
2500	0.0345	21	17	0.0328	20	16	0.0312	19	15	0.0297	18	14	0.0283	18	13
2600	0.0366	21	18	0.0348	20	17	0.0331	19	16	0.0315	19	14	0.0301	18	14
2700	0.0387	22	19	0.0368	21	18	0.0350	20	16	0.0334	19	15	0.0319	18	15
2800	0.0409	24	20	0.0389	22	19	0.0370	21	17	0.0353	20	16	0.0337	19	15
2900	0.0433	24	22	0.0411	23	20	0.0391	22	18	0.0373	20	17	0.0356	19	16
3000	0.0457	25	23	0.0434	24	21	0.0413	23	20	0.0393	22	18	0.0375	21	16
3100	0.0482	25	24	0.0458	24	22	0.0436	23	21	0.0415	22	19	0.0396	21	18
3200	0.0507	26	25	0.0482	25	23	0.0459	24	22	0.0437	23	20	0.0417	22	19
3300	0.0533	27	26	0.0507	26	24	0.0483	25	23	0.0460	24	21	0.0439	22	20
3400	0.0560	29	27	0.0533	27	25	0.0508	26	24	0.0484	25	23	0.0461	24	21
3500	0.0589	29	29	0.0560	28	26	0.0534	26	25	0.0509	25	24	0.0485	24	22
3600	0.0618	30	30	0.0588	29	28	0.0560	27	26	0.0534	26	25	0.0509	26	23

Digitized by Google

TABLE I—CONTINUED.—*Auxiliary B.*

z.	1200.	Δ_z.	Δ_v.	1250.	Δ_z.	Δ_v.	1300.	Δ_z.	Δ_v.	1350.	Δ_z.	Δ_v.	1400.	Δ_z.	Δ_v.
3600	0.1279	49	57	0.1222	47	55	0.1167	45	51	0.1116	44	49	0.1067	43	47
3700	0.1328	49	59	0.1269	47	57	0.1212	46	52	0.1160	45	50	0.1110	43	49
3800	0.1377	50	61	0.1316	48	58	0.1258	47	53	0.1205	45	52	0.1153	44	50
3900	0.1427	50	63	0.1364	48	59	0.1305	47	55	0.1250	46	53	0.1197	45	51
4000	0.1477	52	65	0.1412	50	60	0.1352	48	56	0.1296	47	54	0.1242	45	53
4100	0.1529	52	67	0.1462	50	62	0.1400	49	57	0.1343	47	56	0.1287	46	54
4200	0.1581	53	69	0.1512	52	63	0.1449	50	59	0.1390	48	57	0.1333	47	55
4300	0.1634	54	70	0.1564	52	65	0.1499	50	61	0.1438	49	58	0.1380	47	56
4400	0.1688	55	72	0.1616	52	67	0.1549	51	62	0.1487	50	60	0.1427	48	57
4500	0.1743	55	75	0.1668	54	68	0.1600	52	63	0.1537	50	62	0.1475	49	59
4600	0.1798	57	76	0.1722	55	70	0.1652	53	65	0.1587	51	63	0.1524	50	61
4700	0.1855	57	78	0.1777	55	72	0.1705	53	67	0.1638	52	64	0.1574	51	62
4800	0.1912	58	80	0.1832	56	74	0.1758	54	68	0.1690	53	65	0.1625	51	64
4900	0.1970	59	82	0.1888	57	76	0.1812	55	69	0.1743	53	67	0.1676	52	65
5000	0.2029	60	84	0.1945	58	78	0.1867	56	71	0.1796	55	68	0.1728	53	67
5100	0.2089	60	86	0.2003	58	80	0.1923	57	72	0.1851	55	70	0.1781	53	68
5200	0.2149	61	88	0.2061	59	81	0.1980	58	74	0.1906	56	72	0.1834	54	69
5300	0.2210	62	90	0.2120	60	82	0.2038	58	76	0.1962	56	74	0.1888	55	70
5400	0.2272	63	92	0.2180	61	84	0.2096	59	78	0.2018	58	75	0.1943	56	72
5500	0 2335	64	94	0.2241	62	86	0.2155	60	79	0.2076	58	77	0.1999	57	73
5600	0.2399	64	96	0.2303	63	88	0.2215	61	81	0.2134	59	78	0.2056	57	75
5700	0.2463	66	99	0.2366	63	90	0.2276	61	83	0.2193	59	80	0.2113	58	76
5800	0.2529	67	100	0.2429	65	92	0.2337	63	85	0.2252	61	81	0.2171	59	78
5900	0.2596	68	102	0.2494	65	94	0.2400	63	87	0.2313	62	83	0.2230	60	79
6000	0.2664	68	105	0.2559	66	90	0.2463	64	88	0.2375	62	85	0.2290	61	81
6100	0.2732	69	107	0.2625	67	98	0.2527	65	90	0.2437	63	86	0.2351	61	83
6200	0.2801	71	109	0.2692	68	100	0.2592	66	92	0.2500	65	88	0.2412	63	84
6300	0.2872	71	112	0.2760	69	102	0.2658	67	93	0.2565	65	90	0.2475	63	86
6400	0.2943	73	114	0.2829	69	104	0.2725	67	95	0.2630	66	92	0.2538	64	87
6500	0.3016	73	118	0.2898	71	106	0.2792	69	96	0.2696	66	94	0.2602	65	89
6600	0.3089	74	120	0.2969	72	108	0.2861	70	99	0.2762	68	95	0.2667	66	91
6700	0.3163	75	122	0.3041	73	110	0.2931	71	101	0.2830	68	97	0.2733	66	93
6800	0.3238	77	124	0.3114	74	112	0.3002	72	104	0.2898	70	99	0.2799	68	94

Digitized by Google

TABLE I—CONTINUED.—*Auxiliary B.*

z.	1450.	Δ_s.	Δ_v.	1500.	Δ_s.	Δ_v.	1550.	Δ_s.	Δ_v.	1600.	Δ_s.	Δ_v.	1650.	Δ_s.	Δ_v.
3600	0.1020	41	47	0.0973	40	46	0.0927	39	44	0.0883	38	43	0.0840	37	42
3700	0.1061	42	48	0.1013	41	47	0.0966	40	45	0.0921	39	44	0.0877	38	43
3800	0.1103	43	49	0.1054	42	48	0.1006	41	46	0.0960	40	45	0.0915	39	44
3900	0.1146	43	50	0.1096	42	49	0.1047	41	47	0.1000	40	46	0.0954	39	45
4000	0.1189	44	51	0.1138	43	50	0.1088	42	48	0.1040	41	47	0.0993	40	46
4100	0.1233	45	52	0.1181	44	51	0.1130	42	49	0.1081	41	48	0.1033	40	47
4200	0.1278	46	53	0.1225	44	52	0.1172	43	50	0.1122	42	49	0.1073	41	48
4300	0.1324	46	55	0.1269	45	54	0.1215	44	51	0.1164	43	50	0.1114	42	49
4400	0.1370	46	56	0.1314	45	55	0.1259	45	52	0.1207	44	51	0.1156	42	50
4500	0.1416	47	57	0.1359	46	55	0.1304	46	53	0.1251	44	53	0.1198	43	51
4600	0.1463	49	58	0.1405	47	55	0.1350	45	55	0.1295	45	54	0.1241	44	52
4700	0.1512	49	60	0.1452	48	57	0.1395	46	55	0.1340	45	55	0.1285	44	53
4800	0.1561	50	61	0.1500	48	59	0.1441	47	56	0.1385	46	56	0.1329	45	54
4900	0.1611	50	63	0.1548	49	60	0.1488	48	57	0.1431	47	57	0.1374	46	55
5000	0.1661	52	64	0.1597	50	61	0.1536	49	58	0.1478	47	58	0.1420	46	56
5100	0.1713	52	66	0.1647	51	62	0.1585	50	60	0.1525	48	59	0.1466	47	57
5200	0.1765	53	67	0.1698	52	63	0.1635	49	62	0.1573	48	60	0.1513	48	58
5300	0.1818	53	68	0.1750	52	66	0.1684	51	63	0.1621	50	60	0.1561	48	59
5400	0.1871	55	69	0.1802	53	67	0.1735	52	64	0.1671	51	62	0.1609	49	60
5500	0.1926	55	71	0.1855	54	68	0.1787	52	65	0.1722	51	64	0.1658	50	61
5600	0.1981	56	72	0.1909	54	70	0.1839	52	66	0.1773	52	65	0.1708	51	62
5700	0.2037	56	74	0.1963	55	72	0.1891	54	66	0.1825	52	66	0.1759	51	63
5800	0.2093	58	75	0.2018	56	73	0.1945	55	68	0.1877	53	67	0.1810	52	64
5900	0.2151	58	77	0.2074	57	74	0.2000	56	70	0.1930	54	68	0.1862	53	65
6000	0.2209	59	78	0.2131	58	75	0.2056	57	72	0.1984	55	69	0.1915	54	67
6100	0.2268	60	79	0.2189	58	76	0.2113	57	74	0.2039	56	70	0.1969	54	68
6200	0.2328	61	81	0.2247	60	77	0.2170	58	75	0.2095	57	72	0.2023	55	69
6300	0.2389	62	82	0.2307	60	79	0.2228	58	76	0.2152	57	74	0.2078	56	70
6400	0.2451	62	84	0.2367	61	81	0.2286	60	77	0.2209	58	75	0.2134	57	72
6500	0.2513	63	85	0.2428	61	82	0.2346	60	79	0.2267	59	76	0.2191	57	73
6600	0.2576	64	87	0.2489	63	83	0.2406	60	80	0.2326	60	78	0.2248	59	74
6700	0.2640	65	88	0.2552	63	86	0.2466	62	80	0.2386	60	79	0.2307	59	76
6800	0.2705	66	90	0.2615	64	87	0.2528	63	82	0.2446	61	80	0.2366	60	77

Digitized by Google

TABLE I—CONTINUED.—*Auxiliary B.*

s.	1700.	Δ_s.	Δ_v.	1750.	Δ_s.	Δ_v.	1800.	Δ_s.	Δ_v.	1850.	Δ_s.	Δ_v.	1900.	Δ_s.	Δ_v.
3600	0.0798	36	40	0.0758	34	38	0.0720	34	36	0.0684	32	34	0.0650	31	32
3700	0.0834	37	42	0.0792	36	38	0.0754	34	38	0.0716	33	36	0.0681	32	33
3800	0.0871	38	43	0.0828	37	40	0.0788	36	39	0.0749	34	36	0.0713	33	35
3900	0.0909	38	44	0.0865	38	41	0.0824	36	41	0.0783	35	37	0.0746	33	36
4000	0.0947	39	44	0.0903	38	43	0.0860	37	42	0.0818	36	39	0.0779	35	37
4100	0.0986	39	45	0.0941	38	44	0.0897	37	43	0.0854	37	40	0.0814	35	38
4200	0.1025	40	46	0.0979	39	45	0.0934	38	43	0.0891	37	42	0.0849	36	39
4300	0.1065	41	47	0.1018	40	46	0.0972	39	44	0.0928	38	43	0.0885	37	40
4400	0.1106	41	48	0.1058	41	47	0.1011	40	45	0.0966	39	44	0.0922	38	42
4500	0.1147	42	48	0.1099	41	48	0.1051	40	46	0.1005	39	45	0.0960	38	43
4600	0.1189	43	49	0.1140	42	49	0.1091	41	47	0.1044	40	46	0.0998	39	44
4700	0.1232	43	50	0.1182	42	50	0.1132	41	48	0.1084	40	47	0.1037	40	45
4800	0.1275	44	51	0.1224	43	51	0.1173	42	49	0.1124	41	47	0.1077	40	47
4900	0.1319	45	52	0.1267	43	52	0.1215	43	50	0.1165	42	48	0.1117	41	47
5000	0.1364	45	54	0.1310	45	52	0.1258	43	51	0.1207	43	49	0.1158	42	48
5100	0.1409	46	54	0.1355	45	54	0.1301	44	51	0.1250	43	50	0.1200	42	49
5200	0.1455	47	55	0.1400	45	55	0.1345	45	52	0.1293	44	51	0.1242	43	49
5300	0.1502	47	57	0.1445	46	55	0.1390	45	53	0.1337	44	52	0.1285	43	50
5400	0.1549	48	58	0.1491	47	56	0.1435	46	54	0.1381	45	53	0.1328	44	51
5500	0.1597	49	59	0.1538	48	57	0.1481	47	55	0.1426	45	54	0.1372	45	52
5600	0.1646	50	60	0.1586	48	58	0.1528	47	57	0.1471	47	54	0.1417	45	53
5700	0.1696	50	62	0.1634	49	59	0.1575	48	57	0.1518	47	56	0.1462	46	54
5800	0.1746	51	63	0.1683	50	60	0.1623	49	58	0.1565	48	57	0.1508	47	55
5900	0.1797	51	64	0.1733	51	61	0.1672	49	59	0.1613	48	58	0.1555	48	56
6000	0.1848	53	64	0.1784	51	63	0.1721	50	60	0.1661	49	58	0.1603	48	57
6100	0.1901	53	66	0.1835	52	64	0.1771	51	61	0.1710	49	59	0.1651	48	58
6200	0.1954	54	67	0.1887	53	65	0.1822	52	63	0.1759	51	60	0.1699	50	58
6300	0.2008	54	68	0.1940	53	66	0.1874	52	64	0.1810	51	61	0.1749	50	60
6400	0.2062	56	69	0.1993	54	67	0.1926	53	65	0.1861	52	62	0.1799	51	61
6500	0.2118	56	71	0.2047	55	68	0.1979	54	66	0.1913	53	63	0.1850	52	62
6600	0.2174	57	72	0.2102	56	69	0.2033	55	67	0.1966	54	64	0.1902	52	64
6700	0.2231	58	73	0.2158	56	70	0.2088	55	68	0.2020	54	66	0.1954	53	65
6800	0.2289	59	75	0.2214	57	71	0.2143	56	69	0.2074	55	67	0.2007	54	65

Digitized by Google

TABLE I—CONTINUED.—*Auxiliary B.*

z.	1950.	Δ_z.	Δ_v.	2000.	Δ_z.	Δ_v.	2050.	Δ_z.	Δ_v.	2100.	Δ_z.	Δ_v.	2150.	Δ_z.	Δ_v.
3600	0.0618	30	30	0.0588	29	28	0.0560	27	26	0.0534	26	25	0.0509	25	23
3700	0.0648	30	31	0.0617	29	30	0.0587	29	27	0.0560	27	27	0.0534	26	24
3800	0.0678	32	32	0.0646	30	30	0.0616	29	29	0.0587	27	27	0.0560	26	25
3900	0.0710	32	34	0.0676	31	31	0.0645	29	31	0.0614	29	28	0.0586	28	25
4000	0.0742	34	35	0.0707	32	33	0.0674	31	31	0.0643	30	29	0.0614	28	27
4100	0.0776	34	37	0.0739	33	34	0.0705	31	32	0.0673	30	31	0.0642	29	28
4200	0.0810	35	38	0.0772	34	36	0.0736	33	33	0.0703	31	32	0.0671	30	29
4300	0.0845	35	39	0.0806	34	37	0.0769	33	35	0.0734	32	33	0.0701	31	31
4400	0.0880	37	40	0.0840	36	38	0.0802	34	36	0.0766	33	34	0.0732	31	32
4500	0.0917	37	41	0.0876	36	40	0.0836	35	37	0.0799	34	36	0.0763	33	32
4600	0.0954	38	42	0.0912	37	41	0.0871	36	38	0.0833	34	37	0.0796	33	34
4700	0.0992	38	43	0.0949	37	42	0.0907	37	40	0.0867	36	38	0.0829	34	35
4800	0.1030	40	44	0.0986	39	42	0.0944	37	41	0.0903	37	40	0.0863	36	36
4900	0.1070	40	45	0.1025	39	44	0.0981	38	41	0.0940	37	41	0.0899	36	38
5000	0.1110	41	46	0.1064	40	45	0.1019	39	42	0.0977	38	42	0.0935	37	39
5100	0.1151	42	47	0.1104	40	46	0.1058	40	43	0.1015	38	43	0.0972	38	41
5200	0.1193	42	49	0.1144	41	46	0.1098	40	45	0.1053	39	43	0.1010	38	42
5300	0.1235	42	50	0.1185	42	47	0.1138	41	46	0.1092	40	44	0.1048	39	42
5400	0.1277	43	50	0.1227	42	48	0.1179	41	47	0.1132	41	45	0.1087	40	43
5500	0.1320	44	51	0.1269	43	49	0.1220	42	47	0.1173	41	46	0.1127	40	44
5600	0.1364	44	52	0.1312	44	50	.01262	43	48	0.1214	42	47	0.1167	40	45
5700	0.1408	45	52	0.1356	44	51	0.1305	44	49	0.1256	43	49	0.1207	42	45
5800	0.1453	46	53	0.1400	45	51	0.1349	44	50	0.1299	43	50	0.1249	43	46
5900	0.1499	47	54	0.1445	46	52	0.1393	44	51	0.1342	44	49	0.1292	43	47
6000	0.1546	47	55	0.1491	46	54	0.1437	45	51	0.1386	45	50	0.1335	44	48
6100	0.1593	48	56	0.1537	47	55	0.1482	46	51	0.1431	45	52	0.1379	44	49
6200	0.1641	48	57	0.1584	48	56	0.1528	47	52	0.1476	46	53	0.1423	45	49
6300	0.1689	49	57	0.1632	48	57	0.1575	48	53	0.1522	46	54	0.1468	46	50
6400	0.1738	50	58	0.1680	49	57	0.1623	48	55	0.1568	47	54	0.1514	48	51
6500	0.1788	50	59	0.1729	50	58	0.1671	49	56	0.1615	48	53	0.1562	47	53
6600	0.1838	51	59	0.1779	50	59	0.1720	50	57	0.1663	49	54	0.1609	47	54
6700	0.1889	53	60	0.1829	51	59	0.1770	50	58	0.1712	49	56	0.1656	47	54
6800	0.1942	54	62	0.1880	52	60	0.1820	51	59	0.1761	50	58	0.1703	48	54

Digitized by Google

Digitized by Google

TABLE II.

FOR SPHERICAL PROJECTILES.

u.	$S(u)$.	Diff.	$A(u)$.	Diff.	$I(u)$.	Diff.	$T(u)$.	Diff.
2000	0	25	0.00	1	0.00000	40	0.000	12
1990	25	24	0.01	1	0.00040	40	0.012	13
1980	49	25	0.02	2	0.00080	41	0.025	12
1970	74	25	0.04	4	0.00121	42	0.037	13
1960	99	25	0.08	5	0.00163	42	0.050	13
1950	124	26	0.13	5	0.00205	43	0.063	13
1940	150	25	0.18	7	0.00248	44	0.076	13
1930	175	26	0.25	8	0.00292	44	0.089	13
1920	201	25	0.33	9	0.00336	45	0.102	14
1910	226	26	0.42	11	0.00381	46	0.116	13
1900	252	26	0.53	12	0.00427	46	0.129	14
1890	278	26	0.65	13	0.00473	47	0.143	14
1880	304	26	0.78	14	0.00520	48	0.157	14
1870	330	27	0.92	15	0.00568	49	0.171	14
1860	357	26	1.07	17	0.00617	49	0.185	14
1850	383	26	1.24	19	0.00666	50	0.199	15
1840	409	27	1.43	20	0.00716	51	0.214	14
1830	436	27	1.63	21	0.00767	52	0.228	15
1820	463	27	1.84	23	0.00819	53	0.243	15
1810	490	27	2.07	24	0.00872	54	0.258	15
1800	517	28	2.31	26	0.00926	55	0.273	15
1790	545	27	2.57	27	0.00981	55	0.288	16
1780	572	28	2.84	30	0.01036	57	0.304	15
1770	600	28	3.14	31	0.01093	57	0.319	16
1760	628	28	3.45	33	0.01150	59	0.335	16
1750	656	28	3.78	35	0.01209	59	0.351	16
1740	684	28	4.13	37	0.01268	61	0.367	16
1730	712	29	4.50	39	0.01329	61	0.383	17
1720	741	28	4.89	41	0.01390	63	0.400	16
1710	769	29	5.30	43	0.01453	64	0.416	17
1700	798	29	5.73	45	0.01517	65	0.433	17
1690	827	29	6.18	47	0.01582	66	0.450	18
1680	856	30	6.65	50	0.01648	67	0.468	17
1670	886	29	7.15	52	0.01715	68	0.485	18
1660	915	30	7.67	54	0.01783	70	0.503	18
1650	845	30	8.21	56	0.01853	71	0.521	18

Digitized by Google

TABLE II—CONTINUED.

u.	$S(u)$.	Diff.	$A(u)$.	Diff.	$I(u)$.	Diff.	$T(u)$.	Diff.
1640	975	30	8.77	58	0.01924	72	0.539	19
1630	1005	31	9.35	62	0.01996	74	0.558	18
1620	1036	30	9.97	64	0.02070	75	0.576	19
1610	1066	30	10.61	66	0.02145	77	0.595	19
1600	1096	31	11.27	69	0.02222	78	0.614	19
1590	1127	31	11.96	72	0.02300	79	0.633	20
1580	1158	31	12.68	76	0.02379	81	0.653	20
1570	1189	31	13.44	78	0.02460	82	0.673	20
1560	1220	32	14.22	82	0.02542	84	0.693	20
1550	1252	32	15.04	86	0.02626	86	0.713	21
1540	1284	32	15.90	88	0.02712	87	0.734	21
1530	1316	32	16.78	92	0.02799	89	0.755	21
1520	1348	32	17.70	95	0.02888	91	0.776	21
1510	1380	33	18.65	98	0.02979	93	0.797	22
1500	1413	33	19.63	100	0.03072	94	0.819	22
1490	1446	33	20.63	105	0.03166	96	0.841	22
1480	1479	33	21.68	109	0.03262	98	0.863	22
1470	1512	34	22.77	114	0.03360	101	0.885	23
1460	1546	34	23.91	119	0.03461	103	0.908	23
1450	1580	34	25.10	124	0.03564	105	0.931	24
1440	1614	34	26.34	128	0.03669	107	0.955	24
1430	1648	34	27.62	133	0.03776	109	0.979	24
1420	1682	35	28.95	138	0.03885	112	1.003	25
1410	1717	35	30.33	143	0.03997	114	1.028	25
1400	1752	35	31.76	149	0.04111	116	1.053	26
1390	1787	36	33.25	154	0.04227	119	1.079	26
1380	1823	35	34.79	160	0.04346	122	1.105	26
1370	1858	36	36.39	164	0.04468	124	1.131	27
1360	1894	37	38.03	170	0.04592	127	1.158	27
1350	1931	36	39.73	175	0.04719	129	1.185	27
1340	1967	37	41.48	181	0.04848	133	1.212	27
1330	2004	37	43.29	185	0.04981	136	1.239	28
1320	2041	37	45.14	191	0.05117	139	1.267	27
1310	2078	38	47.05	196	0.05256	142	1.294	28
1300	2116	38	49.01	203	0.05398	144	1.322	29
1290	2154	38	51.04	212	0.05542	148	1.351	30
1280	2192	39	53.16	221	0.05690	152	1.381	30
1270	2231	38	55.37	230	0.05842	156	1.411	31
1260	2269	39	57.67	240	0.05998	160	1.442	31

Digitized by Google

TABLE II—CONTINUED.

u.	$S(u)$.	Diff.	$A(u)$.	Diff.	$I(u)$.	Diff.	$T(u)$.	Diff.
1250	2308	40	60.07	249	0.06158	165	1.473	32
1240	2348	40	62.56	258	0.06323	169	1.505	33
1230	2388	40	65.14	267	0.06492	174	1.538	33
1220	2428	42	67.81	278	0.06666	180	1.571	34
1210	2470	42	70.59	295	0.06846	187	1.605	35
1200	2512	22	73.54	156	0.07033	97	1.640	18
1195	2534	22	75.10	160	0.07130	99	1.658	18
1190	2556	22	76.70	162	0.07229	100	1.676	18
1185	2578	22	78.32	165	0.07329	102	1.694	18
1180	2600	23	79.97	169	0.07431	104	1.712	19
1175	2623	23	81.66	173	0.07535	106	1.731	20
1170	2646	23	83.39	177	0.07641	108	1.751	19
1165	2669	23	85.16	182	0.07749	110	1.770	20
1160	2692	23	86.98	186	0.07859	113	1.790	20
1155	2715	24	88.84	190	0.07972	115	1.810	21
1150	2739	24	90.74	195	0.08087	117	1.831	21
1145	2763	24	92.69	199	0.08204	120	1.852	21
1140	2787	25	94.68	205	0.08324	122	1.873	22
1135	2812	25	96.73	209	0.08446	124	1.895	22
1130	2837	24	98.82	215	0.08570	127	1.917	23
1125	2862	25	100.97	221	0.08697	130	1.940	23
1120	2886	26	103.18	226	0.08827	132	1.963	23
1115	2912	26	105.44	233	0.08959	135	1.986	23
1110	2938	26	107.77	239	0.09094	138	2.009	24
1105	2964	27	110.16	246	0.09232	141	2.033	24
1100	2991	26	112.62	251	0.09373	143	2.057	24
1095	3017	27	115.13	259	0.09516	147	2.081	25
1090	3044	27	117.72	266	0.09663	149	2.106	26
1085	3071	28	120.38	275	0.09812	153	2.132	26
1080	3099	28	123.13	283	0.09965	156	2.158	26
1075	3127	28	125.96	291	0.10121	159	2.184	26
1070	3155	29	128.87	300	0.10280	163	2.210	27
1065	3184	29	131.87	308	0.10443	166	2.237	28
1060	3213	30	134.95	317	0.10609	170	2.265	28
1055	3243	30	138.12	326	0.10779	173	2.293	28
1050	3273	30	141.38	338	0.10952	177	2.321	29
1045	3303	30	144.76	346	0.11129	181	2.350	29
1040	3333	31	148.22	355	0.11310	185	2.379	30
1035	3364	31	151.77	364	0.11495	189	2.409	31

Digitized by Google

TABLE II—CONTINUED.

u.	$S(u)$.	Diff.	$A(u)$.	Diff.	$'I(u)$.	Diff.	$T(u)$.	Diff.
1030	3395	32	155.41	374	0.11684	193	2.440	31
1025	3427	32	159.15	384	0.11877	197	2.471	31
1020	3459	32	162.99	394	0.12074	202	2.502	32
1015	3491	33	166.93	406	0.12276	206	2.534	32
1010	3524	33	170.99	418	0.12482	211	2.566	33
1005	3557	34	175.17	430	0.12693	215	2.599	33
1000	3591	34	179.47	443	0.12908	220	2.632	33
995	3625	35	183.90	456	0.13128	226	2.665	34
990	3660	35	188.46	470	0.13354	231	2.699	35
985	3695	36	193.16	484	0.13585	236	2.734	36
980	3731	36	198.00	498	0.13821	241	2.770	36
975	3767	36	202.98	513	0.14062	246	2.806	37
970	3803	37	208.11	529	0.14308	252	2.843	38
965	3840	37	213.40	546	0.14560	258	2.881	39
960	3877	38	218.86	563	0.14818	264	2.920	39
955	3915	38	224.49	580	0.15082	270	2.959	40
950	3953	39	230.29	600	0.15352	276	2.999	41
945	3992	39	236.29	620	0.15628	283	3.040	42
940	4031	39	242.49	637	0.15911	290	3.082	43
935	4070	40	248.86	657	0.16201	297	3.125	43
930	4110	40	255.43	676	0.16498	304	3.168	44
925	4151	41	262.19	698	0.16802	311	3.212	45
920	4192	42	269.17	720	0.17113	319	3.257	46
915	4234	43	276.37	743	0.17432	327	3.303	47
910	4277	43	283.80	767	0.17759	335	3.350	47
905	4320	43	291.47	793	0.18094	343	3.397	48
900	4363	44	299.40	819	0.18437	352	3.445	49
895	4407	44	307.59	845	0.18789	360	3.494	50
890	4451	45	316.04	873	0.19149	369	3.544	51
885	4496	46	324.77	901	0.19518	378	3.595	52
880	4542	47	333.78	928	0.19896	387	3.647	53
875	4589	47	343.06	961	0.20283	397	3.700	54
870	4636	48	352.67	997	0.20680	407	3.754	55
865	4684	48	362.64	1032	0.21087	418	3.809	56
860	4732	49	372.96	1064	0.21505	428	3.865	57
855	4781	49	383.60	1099	0.21933	439	3.922	58
850	4830	50	394.59	1137	0.22372	451	3.980	59
845	4880	51	405.96	1175	0.22823	462	4.039	61
840	4931	52	417.71	1216	0.23285	476	4.100	61

Digitized by Google

TABLE II—CONTINUED.

u.	$S(u)$.	Diff.	$A(u)$.	Diff.	$I(u)$.	Diff.	$T(u)$.	Diff.
835	4983	53	429.87	1258	0.23761	487	4.161	63
830	5036	53	442.45	1302	0.24248	498	4.224	64
825	5089	54	455.47	1347	0.24746	511	4.288	66
820	5143	55	468.94	1395	0.25257	526	4.354	67
815	5198	55	482.89	1444	0.25783	540	4.421	68
810	5253	56	497.33	1495	0.26323	553	4.489	70
805	5309	57	512.28	1549	0.26876	568	4.559	71
800	5366	58	527.77	1604	0.27444	587	4.630	72
795	5424	59	543.81	1661	0.28031	601	4.702	74
790	5483	59	560.42	1722	0.28632	617	4.776	76
785	5542	60	577.64	1784	0.29249	634	4.852	77
780	5602	61	595.48	1849	0.29883	650	4.929	79
775	5663	62	613.97	1916	0.30533	670	5.008	80
770	5725	63	633.13	1988	0.31203	688	5.088	82
765	5788	64	653.01	2062	0.31891	707	5.170	84
760	5852	65	673.63	2138	0.32598	727	5.254	86
755	5917	66	695.01	2218	0.33325	748	5.340	87
750	5983	67	717.19	2303	0.34073	770	5.427	90
745	6050	68	740.22	2389	0.34843	791	5.517	91
740	6118	69	764.11	2480	0.35634	814	5.608	93
735	6187	69	788.91	2574	0.36448	837	5.701	96
730	6256	71	814.65	2673	0.37285	861	5.797	97
725	6327	72	841.38	2776	0.38146	887	5.894	100
720	6399	73	869.14	2882	0.39033	912	5.994	102
715	6472	74	897.96	2996	0.39945	940	6.096	104
710	6546	75	927.92	3115	0.40885	968	6.200	106
705	6621	77	959.07	3238	0.41853	995	6.306	109
700	6698	78	991.45	3366	0.42848	1024	6.415	111
695	6776	79	1025.2	350	0.43872	1054	6.526	114
690	6855	80	1060.2	364	0.44926	1089	6.640	116
685	6935	81	1096.6	378	0.46015	1128	6.756	119
680	7016	82	1134.4	394	0.47143	1159	6.875	122
675	7098	84	1173.8	409	0.48302	1192	6.997	125
670	7182	85	1214.7	427	0.49194	1228	7.122	127
665	7267	87	1257.4	444	0.50722	1267	7.249	131
660	7354	88	1301.8	463	0.51989	1307	7.380	134
655	7442	89	1348.1	482	0.53296	1349	7.514	137
650	7531	91	1396.3	502	0.54645	1392	7.651	140
645	7622	92	1446.5	523	0.56037	1436	7.791	143

Digitized by Google

TABLE II—CONTINUED.

u.	$S(u)$.	Diff.	$A(u)$.	Diff.	$I(u)$.	Diff.	$T(u)$.	Diff.
640	7714	94	1498.8	546	0.57473	1482	7.934	147
635	7808	95	1553.4	568	0.58955	1529	8.081	150
630	7903	97	1610.2	592	0.60484	1579	8.231	154
625	8000	98	1669.4	618	0.62063	1633	8.385	158
620	8098	100	1731.2	644	0.63696	1690	8.543	162
615	8198	101	1795.6	673	0.65386	1737	8.705	166
610	8299	103	1862.9	702	0.67123	1799	8.871	170
605	8402	105	1933.1	733	0.68922	1859	9.041	174
600	8507	107	2006.4	765	0.70781	1923	9.215	179
595	8614	108	2082.9	800	0.72704	1988	9.394	183
590	8722	111	2162.9	836	0.74692	2055	9.577	188
585	8833	112	2246.5	872	0.76747	2126	9.765	192
580	8945	114	2333.7	911	0.78873	2199	9.957	197
575	9059	116	2424.8	954	0.81072	2276	10.154	203
570	9175	118	2520.2	998	0.83348	2356	10.357	208
565	9293	120	2620.0	1043	0.85704	2440	10.565	213
560	9413	122	2724.3	1091	0.88144	2526	10.778	219
555	9535	124	2833.4	1142	0.90670	2617	10.997	225
550	9659	126	2947.6	1196	0.93287	2711	11.222	231
545	9785	129	3067.2	1252	0.95998	2810	11.453	237
540	9914	131	3192.4	1312	0.98808	2913	11.690	243
535	10045	133	3323.6	1374	1.01721	3019	11.933	250
530	10178	135	3461.0	1440	1.04740	3133	12.183	257
525	10313	138	3605.0	1509	1.07873	3247	12.440	264
520	10451	140	3755.9	1582	1.11120	3366	12.704	271
515	10591	143	3914.1	1660	1.14486	3495	12.975	279
510	10734	146	4080.1	1743	1.17981	3633	13.254	287
505	10880	148	4254.4	1829	1.21614	3779	13.541	295
500	11028	151	4437.3	1920	1.25393	3919	13.836	302
495	11179	153	4629.3	2017	1.29312	4070	14.138	312
490	11332	156	4831.0	2118	1.33382	4232	14.450	320
485	11488	160	5042.8	2226	1.37614	4399	14.770	330
480	11648	162	5265.4	2340	1.42013	4575	15.100	340
475	11810	165	5499.4	2461	1.46588	4760	15.440	350
470	11975	168	5745.5	2588	1.51348	4953	15.790	360
465	12143	172	6004.3	2724	1.56301	5157	16.150	370
460	12315	175	6276.7	2868	1.61458	5368	16.520	382
455	12490	178	6563.5	3020	1.66826	5593	16.902	394
450	12668	-------	6865.5	-------	1.72419	-------	17.296	------

Digitized by Google

AUXILIARY TABLE A FOR SPHERICAL PROJECTILES.

z.	1200.	Δ_z.	Δ_v.	1250.	Δ_z.	Δ_v.	1300.	Δ_z.	Δ_v.	1350.	Δ_z.	Δ_v.	1400.	Δ_z.	Δ_v.
400	0.0094	25	5	0.0089	22	8	0.0081	22	9	0.0072	22	4	0.0069	18	0
500	0.0119	26	8	0.0111	23	8	0.0103	22	9	0.0094	20	7	0.0087	20	3
600	0.0145	27	11	0.0134	24	9	0.0125	22	11	0.0114	22	7	0.0107	20	7
700	0.0172	28	14	0.0158	26	11	0.0147	23	11	0.0136	22	9	0.0127	20	9
800	0.0200	28	16	0.0184	26	14	0.0170	24	12	0.0158	21	11	0.0147	21	9
900	0.0228	28	18	0.0210	27	16	0.0194	25	15	0.0179	23	11	0.0168	21	11
1000	0.0256	28	19	0.0237	28	18	0.0219	25	17	0.0202	24	13	0.0189	22	12
1100	0.0284	29	19	0.0265	27	21	0.0244	27	18	0.0226	24	15	0.0211	22	13
1200	0.0313	29	21	0.0292	28	21	0.0271	27	20	0.0250	25	17	0.0233	23	14
1300	0.0342	30	22	0.0320	28	22	0.0298	27	23	0.0275	26	19	0.0256	24	16
1400	0.0372	31	24	0.0348	28	23	0.0325	27	24	0.0301	26	21	0.0280	25	18
1500	0.0403	32	27	0.0376	29	24	0.0352	27	25	0.0327	27	22	0.0305	25	20
1600	0.0435	32	30	0.0405	31	26	0.0379	28	25	0.0354	27	24	0.0330	26	22
1700	0.0467	33	31	0.0436	32	29	0.0407	29	26	0.0381	26	25	0.0356	26	24
1800	0.0500	34	32	0.0468	31	32	0.0436	30	29	0.0407	28	25	0.0382	26	24
1900	0.0534	35	35	0.0499	32	33	0.0466	31	31	0.0435	29	27	0.0408	27	25
2000	0.0569	34	38	0.0531	33	34	0.0497	31	33	0.0464	30	29	0.0435	27	26
2100	0.0603	35	39	0.0564	34	36	0.0528	31	34	0.0494	31	32	0.0462	29	28
2200	0.0638	37	40	0.0598	34	39	0.0559	33	34	0.0525	29	34	0.0491	29	30
2300	0.0675	38	43	0.0632	34	40	0.0592	34	38	0.0554	32	34	0.0520	30	32
2400	0.0713	37	47	0.0666	37	40	0.0626	33	40	0.0586	32	36	0.0550	30	34
2500	0.0750	38	47	0.0703	36	44	0.0659	34	41	0.0618	33	38	0.0580	31	35
2600	0.0788	38	49	0.0739	37	46	0.0693	36	42	0.0651	32	40	0.0611	32	36
2700	0.0826	41	50	0.0776	37	47	0.0729	36	46	0.0683	35	40	0.0643	32	39
2800	0.0867	40	54	0.0813	38	48	0.0765	36	47	0.0718	35	43	0.0675	32	40
2900	0.0907	41	56	0.0851	40	50	0.0801	37	48	0.0753	35	46	0.0707	34	41
3000	0.0948	42	57	0.0891	39	53	0.0838	37	50	0.0788	35	47	0.0741	34	43
3100	0.0990	43	60	0.0930	40	55	0.0875	39	52	0.0823	37	48	0.0775	35	45
3200	0.1033	43	63	0.0970	42	56	0.0914	39	54	0.0860	37	50	0.0810	35	47
3300	0.1076	44	64	0.1012	41	59	0.0953	40	56	0.0897	39	52	0.0845	37	47
3400	0.1120	44	67	0.1053	44	60	0.0993	41	57	0.0936	38	54	0.0882	36	50

Digitized by Google

AUXILIARY TABLE A FOR SPHERICAL PROJECTILES—CONTINUED.

s.	1450.	Δ_s.	Δ_v.	1500.	Δ_s.	Δ_v.	1550.	Δ_s.	Δ_v.	1600.	Δ_s.	Δ_v.	1650.	Δ_s.	Δ_v.
400	0.0069	15	8	0.0061	16	5	0.0056	16	4	0.0052	14	2	0.0050	13	3
500	0.0084	16	7	0.0077	17	5	0.0072	16	6	0.0066	16	3	0.0063	13	4
600	0.0100	18	6	0.0094	16	6	0.0088	16	6	0.0082	15	6	0.0076	14	4
700	0.0118	20	8	0.0110	17	6	0.0104	16	7	0.0097	16	7	0.0090	15	5
800	0.0138	19	11	0.0127	19	7	0.0120	16	7	0.0113	16	8	0.0105	16	6
900	0.0157	20	11	0.0146	19	10	0.0136	17	7	0.0129	16	8	0.0121	15	8
1000	0.0177	21	12	0.0165	19	12	0.0153	18	8	0.0145	16	9	0.0136	16	8
1100	0.0198	21	14	0.0184	20	13	0.0171	18	10	0.0161	17	9	0.0152	16	9
1200	0.0219	21	15	0.0204	20	15	0.0189	20	11	0.0178	18	10	0.0168	16	10
1300	0.0240	22	16	0.0224	20	15	0.0209	20	13	0.0196	19	12	0.0184	18	10
1400	0.0262	23	18	0.0244	21	15	0.0229	20	14	0.0215	19	13	0.0202	18	12
1500	0.0285	23	20	0.0265	22	16	0.0249	20	15	0.0234	19	14	0.0220	18	13
1600	0.0308	24	21	0.0287	23	18	0.0269	21	16	0.0253	20	15	0.0238	19	14
1700	0.0332	26	22	0.0310	24	20	0.0290	22	17	0.0273	20	16	0.0257	19	16
1800	0.0358	25	24	0.0334	24	22	0.0312	23	19	0.0293	21	17	0.0276	19	16
1900	0.0383	26	25	0.0358	24	23	0.0335	23	21	0.0314	22	19	0.0295	21	16
2000	0.0409	25	27	0.0382	25	24	0.0358	24	22	0.0336	22	20	0.0316	21	18
2100	0.0434	27	27	0.0407	25	25	0.0382	24	24	0.0358	23	21	0.0337	21	20
2200	0.0461	27	29	0.0432	26	26	0.0406	25	25	0.0381	24	23	0.0358	23	21
2300	0.0488	28	30	0.0458	26	27	0.0431	25	26	0.0405	24	24	0.0381	23	23
2400	0.0516	29	32	0.0484	27	28	0.0456	25	27	0.0429	24	25	0.0404	23	24
2500	0.0545	30	34	0.0511	28	30	0.0481	26	28	0.0453	25	26	0.0427	24	25
2600	0.0575	29	36	0.0539	29	32	0.0507	27	29	0.0478	25	27	0.0451	24	26
2700	0.0604	31	36	0.0568	29	34	0.0534	28	31	0.0503	26	28	0.0475	24	26
2800	0.0635	31	38	0.0597	29	35	0.0562	28	33	0.0529	27	30	0.0499	26	27
2900	0.0666	32	40	0.0626	31	36	0.0590	29	34	0.0556	28	31	0.0525	26	29
3000	0.0698	32	41	0.0657	31	38	0.0619	29	35	0.0584	28	33	0.0551	27	30
3100	0.0730	33	42	0.0688	31	40	0.0648	30	36	0.0612	28	34	0.0578	28	32
3200	0.0763	35	44	0.0719	32	41	0.0678	30	38	0.0640	30	34	0.0606	27	34
3300	0.0798	34	47	0.0751	33	43	0.0708	31	38	0.0670	30	37	0.0633	28	34
3400	0.0832	35	48	0.0784	34	45	0.0739	33	39	0.0700	30	39	0.0661	30	35

Digitized by Google

AUXILIARY TABLE A FOR SPHERICAL PROJECTILES—CONTINUED.

s.	1700.	Δ_s.	Δ_v.	1750.	Δ_s.	Δ_v.
400	0.0047	12	3	0.0044	12	-----
500	0.0059	13	3	0.0056	13	-----
600	0.0072	13	3	0.0069	12	-----
700	0.0085	14	4	0.0081	13	-----
800	0.0099	14	5	0.0094	13	-----
900	0.0113	15	6	0.0107	14	-----
1000	0.0128	15	7	0.0121	14	-----
1100	0.0143	15	8	0.0135	15	-----
1200	0.0158	16	8	0.0150	15	-----
1300	0.0174	16	9	0.0165	15	-----
1400	0.0190	17	10	0.0180	15	-----
1500	0.0207	17	12	0.0195	16	-----
1600	0.0224	17	13	0.0211	17	-----
1700	0.0241	19	13	0.0228	17	-----
1800	0.0260	19	15	0.0245	18	-----
1900	0.0279	19	16	0.0263	18	-----
2000	0.0298	19	17	0.0281	19	-----
2100	0.0317	20	17	0.0300	19	-----
2200	0.0337	21	18	0.0319	19	-----
2300	0.0358	22	20	0.0338	21	-----
2400	0.0380	22	21	0.0359	21	-----
2500	0.0402	23	22	0.0380	21	-----
2600	0.0425	24	24	0.0401	23	-----
2700	0.0449	23	25	0.0424	22	-----
2800	0.0472	24	26	0.0446	24	-----
2900	0.0496	25	26	0.0470	23	-----
3000	0.0521	25	28	0.0493	24	-----
3100	0.0546	26	29	0.0517	25	-----
3200	0.0572	27	30	0.0542	25	-----
3300	0.0599	27	32	0.0567	26	-----
3400	0.0626	28	33	0.0593	27	-----

Digitized by Google

AUXILIARY TABLE A FOR SPHERICAL PROJECTILES—CONTINUED.

z.	1200.	Δ_s.	Δ_v.	1250.	Δ_s.	Δ_v.	1300.	Δ_s.	Δ_v.	1350.	Δ_s.	Δ_v.	1400.	Δ_s.	Δ_v.
3400	0.1120	44	67	0.1053	44	60	0.0993	41	57	0.0936	38	54	0.0882	36	50
3500	0.1164	45	67	0.1097	43	63	0.1034	41	60	0.0974	39	56	0.0918	38	51
3600	0.1209	46	69	0.1140	44	65	0.1075	42	62	0.1013	42	57	0.0956	38	53
3700	0.1255	47	71	0.1184	44	67	0.1117	42	62	0.1055	40	61	0.0994	39	55
3800	0.1302	48	74	0.1228	45	69	0.1159	44	64	0.1095	41	62	0.1033	40	56
3900	0.1350	48	77	0.1273	47	70	0.1203	43	67	0.1136	42	63	0.1073	41	59
4000	0.1398	49	78	0.1320	46	74	0.1246	45	68	0.1178	43	64	0.1114	40	61
4100	0.1447	49	81	0.1366	48	75	0.1291	46	70	0.1221	43	67	0.1154	42	61
4200	0.1496	51	82	0.1414	48	77	0.1337	46	73	0.1264	45	68	0.1196	42	63
4300	0.1547	51	85	0.1462	49	79	0.1383	47	74	0.1309	45	71	0.1238	43	65
4400	0.1598	52	87	0.1511	49	81	0.1430	48	76	0.1354	45	73	0.1281	44	67
4500	0.1650	53	90	0.1560	51	82	0.1478	48	79	0.1399	47	74	0.1325	45	69
4600	0.1703	54	92	0.1611	51	85	0.1526	49	80	0.1446	47	76	0.1370	45	71
4700	0.1757	54	95	0.1662	52	87	0.1575	50	82	0.1493	48	78	0.1415	46	72
4800	0.1811	55	97	0.1714	53	89	0.1625	50	84	0.1541	48	80	0.1461	47	74
4900	0.1866	56	99	0.1767	54	92	0.1675	52	86	0.1589	49	81	0.1508	47	76
5000	0.1922	56	101	0.1821	54	94	0.1727	52	89	0.1638	51	83	0.1555	48	77
5100	0.1978	58	103	0.1875	55	96	0.1779	53	90	0.1689	51	86	0.1603	49	79
5200	0.2036	57	106	0.1930	56	98	0.1832	54	92	0.1740	52	88	0.1652	50	82
5300	0.2093	60	107	0.1986	56	100	0.1886	54	94	0.1792	52	90	0.1702	51	84
5400	0.2153	59	111	0.2042	57	102	0.1940	55	96	0.1844	53	91	0.1753	51	86
5500	0.2212	61	113	0.2099	59	104	0.1995	56	98	0.1897	53	93	0.1804	51	88
5600	0.2273	61	115	0.2158	59	107	0.2051	57	101	0.1950	55	95	0.1855	53	89
5700	0.2334	63	117	0.2217	59	109	0.2108	58	103	0.2005	56	97	0.1908	53	91
5800	0.2397	63	121	0.2276	61	110	0.2166	58	105	0.2061	56	100	0.1961	55	93
5900	0.2460	64	123	0.2337	62	113	0.2224	59	107	0.2117	57	101	0.2016	55	95
6000	0.2524	65	125	0.2399	63	116	0.2283	60	109	0.2174	58	103	0.2071	56	97
6100	0.2589	66	127	0.2462	63	119	0.2343	62	111	0.2232	59	105	0.2127	56	99
6200	0.2655	66	130	0.2525	63	120	0.2405	61	114	0.2291	59	108	0.2183	57	101
6300	0.2721	67	133	0.2588	66	122	0.2466	63	116	0.2350	61	110	0.2240	59	102
6400	0.2788	68	134	0.2654	65	125	0.2529	62	118	0.2411	61	112	0.2299	59	105

Digitized by Google

AUXILIARY TABLE A FOR SPHERICAL PROJECTILES—CONTINUED.

z.	1450.	Δ_s.	Δ_v.	1500.	Δ_s.	Δ_v.	1550.	Δ_s.	Δ_v.	1600.	Δ_s.	Δ_v.	1650.	Δ_s.	Δ_v.
3400	0.0832	35	48	0.0784	34	45	0.0739	33	39	0.0700	30	39	0.0661	30	35
3500	0.0867	36	49	0.0818	34	46	0.0772	34	42	0.0730	31	39	0.0691	30	37
3600	0.0903	36	51	0.0852	35	46	0.0806	33	45	0.0761	32	40	0.0721	30	39
3700	0.0939	38	52	0.0887	35	48	0.0839	34	46	0.0793	33	42	0.0751	31	39
3800	0.0977	37	55	0.0922	37	49	0.0873	34	47	0.0826	33	44	0.0782	32	41
3900	0.1014	39	55	0.0959	37	52	0.0907	36	48	0.0859	34	45	0.0814	33	43
4000	0.1053	40	57	0.0996	37	53	0.0943	36	50	0.0893	34	46	0.0847	32	44
4100	0.1093	40	60	0.1033	39	54	0.0979	36	52	0.0927	35	48	0.0879	34	44
4200	0.1133	40	61	0.1072	39	57	0.1015	38	53	0.0962	36	49	0.0913	34	46
4300	0.1173	41	62	0.1111	40	58	0.1053	38	55	0.0998	37	51	0.0947	36	48
4400	0.1214	42	63	0.1151	40	60	0.1091	39	56	0.1035	37	52	0.0983	35	50
4500	0.1256	43	65	0.1191	41	61	0.1130	39	58	0.1072	38	54	0.1018	37	50
4600	0.1299	44	67	0.1232	41	63	0.1169	40	59	0.1110	39	55	0.1055	37	53
4700	0.1343	44	70	0.1273	43	64	0.1209	41	60	0.1149	39	57	0.1092	38	54
4800	0.1387	45	71	0.1316	43	66	0.1250	41	62	0.1188	40	58	0.1130	38	55
4900	0.1432	46	73	0.1359	44	68	0.1291	43	63	0.1228	40	60	0.1168	39	56
5000	0.1478	46	75	0.1403	45	69	0.1334	43	66	0.1268	41	61	0.1207	40	58
5100	0.1524	46	76	0.1448	45	71	0.1377	43	68	0.1309	43	62	0.1247	40	59
5200	0.1570	48	77	0.1493	46	73	0.1420	45	68	0.1352	42	65	0.1287	41	61
5300	0.1618	49	79	0.1539	46	74	0.1465	45	71	0.1394	44	66	0.1328	43	62
5400	0.1667	49	82	0.1585	48	75	0.1510	45	72	0.1438	44	67	0.1371	42	65
5500	0.1716	50	83	0.1633	48	78	0.1555	46	73	0.1482	45	69	0.1413	43	65
5600	0.1766	51	85	0.1681	50	80	0.1601	48	74	0.1527	45	71	0.1456	45	67
5700	0.1817	51	86	0.1731	49	82	0.1649	48	77	0.1572	46	71	0.1501	44	68
5800	0.1868	53	88	0.1780	50	83	0.1697	49	79	0.1618	48	73	0.1545	45	69
5900	0.1921	53	91	0.1830	52	84	0.1746	50	80	0.1666	48	76	0.1590	47	71
6000	0.1974	54	92	0.1882	52	86	0.1796	49	82	0.1714	48	77	0.1637	47	73
6100	0.2028	54	94	0.1934	52	89	0.1845	51	83	0.1762	50	78	0.1684	48	75
6200	0.2082	56	96	0.1986	54	90	0.1896	52	84	0.1812	49	80	0.1732	48	77
6300	0.2138	56	98	0.2040	54	92	0.1948	53	87	0.1861	51	81	0.1780	49	78
6400	0.2194	57	100	0.2094	55	93	0.2001	53	89	0.1912	52	83	0.1829	50	79

Digitized by Google

AUXILIARY TABLE A FOR SPHERICAL PROJECTILES—CONTINUED.

s.	1700.	Δ_s.	Δ_v.	1750.	Δ_s.	Δ_v.
3400	0.0626	28	33	0.0593	27	-----
3500	0.0654	28	34	0.0620	27	-----
3600	0.0682	30	35	0.0647	28	-----
3700	0.0712	29	37	0.0675	28	-----
3800	0.0741	30	38	0.0703	29	-----
3900	0.0771	32	39	0.0732	30	-----
4000	0.0803	32	41	0.0762	30	-----
4100	0.0835	32	43	0.0792	32	-----
4200	0.0867	32	43	0.0824	32	-----
4300	0.0899	34	43	0.0856	31	-----
4400	0.0933	35	46	0.0887	33	-----
4500	0.0968	34	48	0.0920	34	-----
4600	0.1002	36	48	0.0954	34	-----
4700	0.1038	37	50	0.0988	35	-----
4800	0.1075	37	52	0.1023	36	-----
4900	0.1112	37	53	0.1059	36	-----
5000	0.1149	39	54	0.1095	38	-----
5100	0.1188	38	55	0.1133	37	-----
5200	0.1226	40	56	0.1170	38	-----
5300	0.1266	40	58	0.1208	39	-----
5400	0.1306	42	59	0.1247	39	-----
5500	0.1348	41	62	0.1286	41	-----
5600	0.1389	44	62	0.1327	41	-----
5700	0.1433	43	65	0.1368	42	-----
5800	0.1476	43	66	0.1410	43	-----
5900	0.1519	45	66	0.1453	43	-----
6000	0.1564	45	68	0.1496	43	-----
6100	0.1609	46	70	0.1539	45	-----
6200	0.1655	47	71	0.1584	45	-----
6300	0.1702	48	73	0.1629	47	-----
6400	0.1750	48	74	0.1676	47	-----

Digitized by Google

AUXILIARY TABLE A FOR SPHERICAL PROJECTILES—CONTINUED.

z.	1200.	Δ_z.	Δ_v.	1250.	Δ_z.	Δ_v.	1300.	Δ_z.	Δ_v.	1350.	Δ_z.	Δ_v.	1400.	Δ_z.	Δ_v.
6400	0.2788	68	134	0.2654	65	125	0.2529	62	118	0.2411	61	112	0.2299	59	105
6500	0.2856	69	137	0.2719	66	128	0.2591	65	119	0.2472	62	114	0.2358	60	107
6600	0.2925	70	140	0.2785	68	129	0.2656	65	122	0.2534	63	116	0.2418	61	109
6700	0.2995	71	142	0.2853	68	132	0.2721	66	124	0.2597	64	118	0.2479	61	111
6800	0.3066	71	145	0.2921	69	134	0.2787	67	126	0.2661	63	121	0.2540	62	113
6900	0.3137	73	147	0.2990	70	136	0.2854	67	130	0.2724	66	122	0.2602	64	114
7000	0.3210	74	150	0.3060	70	139	0.2921	69	131	0.2790	66	124	0.2666	63	117
7100	0.3284	74	154	0.3130	72	140	0.2990	69	134	0.2856	67	127	0.2729	65	118
7200	0.3358	76	156	0.3202	73	143	0.3059	70	136	0.2923	68	129	0.2794	65	121
7300	0.3434	75	159	0.3275	74	146	0.3129	71	138	0.2991	69	132	0.2859	67	122
7400	0.3509	77	160	0.3349	74	149	0.3200	72	140	0.3060	69	134	0.2926	68	125
7500	0.3586	78	163	0.3423	75	151	0.3272	73	143	0.3129	70	135	0.2994	68	128
7600	0.3664	79	166	0.3498	77	153	0.3345	74	146	0.3199	72	137	0.3062	69	130
7700	0.3743	80	168	0.3575	77	156	0.3419	74	148	0.3271	73	140	0.3131	70	132
7800	0.3823	81	171	0.3652	78	159	0.3493	75	149	0.3344	73	143	0.3201	72	134
7900	0.3904	82	174	0.3730	78	162	0.3568	77	151	0.3417	73	144	0.3273	71	137
8000	0.3986	----	178	0.3808	----	163	0.3645	----	155	0.3490	----	146	0.3344	----	138

Digitized by Google

AUXILIARY TABLE A FOR SPHERICAL PROJECTILES—CONTINUED.

z.	1450.	Δ_z.	Δ_v.	1500.	Δ_z.	Δ_v.	1550.	Δ_z.	Δ_v.	1600.	Δ_z.	Δ_v.	1650.	Δ_z.	Δ_v.
6400	0.2194	57	100	0.2094	55	93	0.2001	53	89	0.1912	52	83	0.1829	50	79
6500	0.2251	58	102	0.2149	56	95	0.2054	54	90	0.1964	52	85	0.1879	51	81
6600	0.2309	59	104	0.2205	57	97	0.2108	55	92	0.2016	53	86	0.1930	51	83
6700	0.2368	59	106	0.2262	57	99	0.2163	56	94	0.2069	54	88	0.1981	52	84
6800	0.2427	61	108	0.2319	59	100	0.2219	56	96	0.2123	54	90	0.2033	53	85
6900	0.2488	61	110	0.2378	59	103	0.2275	57	98	0.2177	56	91	0.2086	54	87
7000	0.2549	62	112	0.2437	60	105	0.2332	59	99	0.2233	56	93	0.2140	54	89
7100	0.2611	62	114	0.2497	60	106	0.2391	59	102	0.2289	58	95	0.2194	56	90
7200	0.2673	64	116	0.2557	63	107	0.2450	59	103	0.2347	58	97	0.2250	56	93
7300	0.2737	64	117	0.2620	62	111	0.2509	61	104	0.2405	59	99	0.2306	57	94
7400	0.2801	65	119	0.2682	63	112	0.2570	61	106	0.2464	59	101	0.2363	58	96
7500	0.2866	66	121	0.2745	64	114	0.2631	62	108	0.2523	61	102	0.2421	59	97
7600	0.2932	67	123	0.2809	65	116	0.2693	63	109	0.2584	60	104	0.2480	59	99
7700	0.2999	68	125	0.2874	66	118	0.2756	64	112	0.2644	62	105	0.2539	60	101
7800	0.3067	69	127	0.2940	66	120	0.2820	65	114	0.2706	63	107	0.2599	61	102
7900	0.3136	70	130	0.3006	68	121	0.2885	65	116	0.2769	64	109	0.2660	62	104
8000	0.3206	----	132	0.3074	----	124	0.2950	----	117	0.2833	----	111	0.2722	----	106

Digitized by Google

AUXILIARY TABLE A FOR SPHERICAL PROJECTILES—CONTINUED.

z.	1700.	Δ_z.	Δ_v.	1750.	Δ_z.	Δ_v.
6400	0.1750	48	74	0.1676	47	-----
6500	0.1798	49	75	0.1723	47	-----
6600	0.1847	50	77	0.1770	48	-----
6700	0.1897	51	79	0.1818	49	-----
6800	0.1948	51	81	0.1867	50	-----
6900	0.1999	52	82	0.1917	51	-----
7000	0.2051	53	83	0.1968	51	-----
7100	0.2104	53	85	0.2019	52	-----
7200	0.2157	55	86	0.2071	53	-----
7300	0.2212	55	88	0.2124	54	-----
7400	0.2267	57	89	0.2178	54	-----
7500	0.2324	57	92	0.2232	56	-----
7600	0.2381	57	93	0.2288	56	-----
7700	0.2438	59	94	0.2344	57	-----
7800	0.2497	59	96	0.2401	57	-----
7900	0.2556	60	98	0.2458	59	-----
8000	0.2616	-----	99	0.2517	-----	-----

Digitized by Google

AUXILIARY TABLE B FOR SPHERICAL PROJECTILES.

z.	1200.	Δ_z.	Δ_v.	1250.	Δ_z.	Δ_v.	1300.	Δ_z.	Δ_v.	1350.	Δ_z.	Δ_v.	1400.	Δ_z.	Δ_v.
400	0.0098	28	9	0.0089	27	5	0.0084	24	3	0.0081	21	7	0.0074	21	10
500	0.0126	29	10	0.0116	28	8	0.0108	25	6	0.0102	23	7	0.0095	21	10
600	0.0155	29	11	0.0144	28	11	0.0133	27	8	0.0125	24	9	0.0116	23	9
700	0.0184	31	12	0.0172	30	12	0.0160	28	10	0.0149	26	10	0.0139	24	10
800	0.0215	32	13	0.0202	30	14	0.0188	29	13	0.0175	28	12	0.0163	25	11
900	0.0247	34	15	0.0232	31	15	0.0217	30	14	0.0203	29	15	0.0188	27	12
1000	0.0281	36	18	0.0263	33	16	0.0247	31	15	0.0232	30	17	0.0215	28	15
1100	0.0317	37	21	0.0296	34	18	0.0278	32	16	0.0262	30	19	0.0243	30	17
1200	0.0354	38	24	0.0330	36	20	0.0310	34	18	0.0292	32	19	0.0273	30	19
1300	0.0392	39	26	0.0366	37	22	0.0344	35	20	0.0324	33	21	0.0303	32	20
1400	0.0431	40	28	0.0403	39	24	0.0379	37	22	0.0357	34	22	0.0335	33	22
1500	0.0471	41	29	0.0442	40	26	0.0416	38	25	0.0391	36	23	0.0368	33	23
1600	0.0512	43	30	0.0482	41	28	0.0454	39	27	0.0427	37	26	0.0401	35	24
1700	0.0555	45	32	0.0523	42	30	0.0493	40	29	0.0464	39	28	0.0436	37	25
1800	0.0600	45	35	0.0565	44	32	0.0533	41	30	0.0503	40	30	0.0473	38	28
1900	0.0645	47	36	0.0609	46	35	0.0574	43	31	0.0543	41	32	0.0511	39	30
2000	0.0692	50	37	0.0655	45	38	0.0617	45	33	0.0584	42	34	0.0550	41	31
2100	0.0742	50	42	0.0700	48	38	0.0662	46	36	0.0626	43	35	0.0591	42	33
2200	0.0792	51	44	0.0748	49	40	0.0708	47	39	0.0669	45	36	0.0633	43	35
2300	0.0843	53	46	0.0797	50	42	0.0755	48	41	0.0714	47	38	0.0676	44	37
2400	0.0896	54	49	0.0847	52	44	0.0803	50	42	0.0761	48	41	0.0720	46	38
2500	0.0950	55	51	0.0899	54	46	0.0853	51	44	0.0809	49	43	0.0766	47	40
2600	0.1005	57	52	0.0953	55	49	0.0904	52	46	0.0858	50	45	0.0813	49	42
2700	0.1062	59	54	0.1008	56	52	0.0956	54	48	0.0908	52	46	0.0862	50	44
2800	0.1121	60	57	0.1064	57	54	0.1010	56	50	0.0960	54	48	0.0912	52	46
2900	0.1181	61	60	0.1121	59	55	0.1066	57	52	0.1014	55	50	0.0964	52	48
3000	0.1242	63	62	0.1180	61	57	0.1123	58	54	0.1069	56	53	0.1016	55	49
3100	0.1305	65	64	0.1241	62	60	0.1181	60	56	0.1125	58	54	0.1071	55	52
3200	0.1370	66	67	0.1303	64	62	0.1241	61	58	0.1183	59	57	0.1126	57	53
3300	0.1436	68	69	0.1367	65	65	0.1302	63	60	0.1242	60	59	0.1183	59	55
3400	0.1504	69	72	0.1432	67	67	0.1365	65	63	0.1302	62	60	0.1242	60	57
3500	0.1573	71	74	0.1499	68	69	0.1430	66	66	0.1364	64	62	0.1302	61	59

Digitized by Google

AUXILIARY TABLE B FOR SPHERICAL PROJECTILES—CONTINUED.

z.	1450.	Δ_z.	Δ_v.	1500.	Δ_z.	Δ_v.	1550.	Δ_z.	Δ_v.	1600.	Δ_z.	Δ_v.	1650.	Δ_z.	Δ_v.
400	0.0064	21	1	0.0063	18	3	0.0060	16	3	0.0057	16	5	0.0052	16	2
500	0.0085	22	4	0.0081	19	5	0.0076	18	3	0.0073	16	5	0.0068	16	4
600	0.0107	22	7	0.0100	21	6	0.0094	19	5	0.0089	17	5	0.0084	17	5
700	0.0129	23	8	0.0121	22	8	0.0113	20	7	0.0106	18	5	0.0101	17	6
800	0.0152	24	9	0.0143	22	10	0.0133	22	9	0.0124	20	6	0.0118	18	7
900	0.0176	24	11	0.0165	23	10	0.0155	22	11	0.0144	21	8	0.0136	19	8
1000	0.0200	26	12	0.0188	25	11	0.0177	23	12	0.0165	22	10	0.0155	21	9
1100	0.0226	28	13	0.0213	25	13	0.0200	24	13	0.0187	23	11	0.0176	22	11
1200	0.0254	29	16	0.0238	27	14	0.0224	25	14	0.0210	24	12	0.0198	23	13
1300	0.0283	30	18	0.0265	29	16	0.0249	26	15	0.0234	25	13	0.0221	23	14
1400	0.0313	32	19	0.0294	30	19	0.0275	28	16	0.0259	26	15	0.0244	25	14
1500	0.0345	32	21	0.0324	31	21	0.0303	30	18	0.0285	28	16	0.0269	16	16
1600	0.0377	34	22	0.0355	32	22	0.0333	31	20	0 0313	29	18	0.0295	27	17
1700	0.0411	34	24	0.0387	33	23	0.0364	32	22	0.0342	30	20	0.0322	28	18
1800	0.0445	36	25	0.0420	34	24	0.0396	33	24	0.0372	32	22	0.0350	31	19
1900	0.0481	38	27	0.0454	36	25	0.0429	34	25	0.0404	33	23	0.0381	31	23
2000	0.0519	39	29	0.0490	37	27	0.0463	35	26	0.0437	34	25	0.0412	33	24
2100	0.0558	40	31	0.0527	39	29	0.0498	37	27	0.0471	35	26	0.0445	34	25
2200	0.0598	41	32	0.0566	39	31	0.0535	38	29	0.0506	36	27	0.0479	34	27
2300	0.0639	43	34	0.0605	41	32	0.0573	39	31	0.0542	38	29	0.0513	36	27
2400	0.0682	44	36	0.0646	42	34	0.0612	41	32	0.0580	39	31	0.0549	37	28
2500	0.0726	45	38	0.0688	44	35	0.0653	42	34	0.0619	40	33	0.0586	39	30
2600	0.0771	47	39	0.0732	45	37	0.0695	43	36	0.0659	42	34	0.0625	40	32
2700	0.0818	48	41	0.0777	46	39	0.0738	44	37	0.0701	43	36	0.0665	42	34
2800	0.0866	50	43	0.0823	48	41	0.0782	46	38	0.0744	44	37	0.0707	42	36
2900	0.0916	51	45	0.0871	49	43	0.0828	47	40	0.0788	45	39	0.0749	44	36
3000	0.0967	52	47	0.0920	51	45	0.0875	49	42	0.0833	47	40	0.0793	45	38
3100	0.1019	54	48	0.0971	51	47	0.0924	51	44	0.0880	48	42	0.0838	47	39
3200	0.1073	55	51	0.1022	53	47	0.0975	52	47	0.0928	50	43	0.0885	48	41
3300	0.1128	57	53	0.1075	55	48	0.1027	52	49	0.0978	51	45	0.0933	50	43
3400	0.1185	58	55	0.1130	57	51	0.1079	54	50	0.1029	53	46	0.0983	51	45
3500	0.1243	59	56	0.1187	57	54	0.1133	55	51	0.1082	54	48	0.1034	52	47

Digitized by Google

AUXILIARY TABLE B FOR SPHERICAL PROJECTILES—CONTINUED.

s.	1700.	Δ_s.	Δ_v.	1750.	Δ_s.	Δ_v.
400	0.0050	14	3	0.0047	13	-----
500	0.0064	15	4	0.0060	14	-----
600	0.0079	16	5	0.0074	15	-----
700	0.0095	16	6	0.0089	16	-----
800	0.0111	17	6	0.0105	16	-----
900	0.0128	18	7	0.0121	17	-----
1000	0.0146	19	8	0.8138	19	-----
1100	0.0165	20	8	0.0157	18	-----
1200	0.0185	22	10	0.0175	20	-----
1300	0.0207	23	12	0.0195	21	-----
1400	0.0230	23	14	0.0216	23	-----
1500	0.0253	25	14	0.0239	24	-----
1600	0.0278	26	15	0.0263	24	-----
1700	0.0304	27	17	0.0287	26	-----
1800	0.0331	27	18	0.0313	26	-----
1900	0.0358	30	19	0.0339	28	-----
2000	0.0388	32	21	0.0367	29	-----
2100	0.0420	32	24	0.0396	31	-----
2200	0.0452	34	25	0.0427	33	-----
2300	0.0486	35	26	0.0460	33	-----
2400	0.0521	35	28	0.0493	35	-----
2500	0.0556	37	28	0.0528	35	-----
2600	0.0593	38	30	0.0563	37	-----
2700	0.0631	40	31	0.0600	38	-----
2800	0.0671	42	33	0.0638	40	-----
2900	0.0713	42	35	0.0678	41	-----
3000	0.0755	44	36	0.0719	42	-----
3100	0.0799	45	38	0.0761	43	-----
3200	0.0844	46	40	0.0804	45	-----
3300	0.0890	48	41	0.0849	47	-----
3400	0.0938	49	42	0.0896	47	-----
3500	0.0987	51	44	0.0943	49	-----

Digitized by Google

AUXILIARY TABLE B FOR SPHERICAL PROJECTILES—CONTINUED.

z.	1200.	Δ_z.	Δ_v.	1250.	Δ_z.	Δ_v.	1300.	Δ_z.	Δ_v.	1350.	Δ_z.	Δ_v.	1400.	Δ_z.	Δ_v.
3500	0.1573	71	74	0.1499	68	69	0.1430	66	66	0.1364	64	62	0.1312	61	59
3600	0.1644	73	77	0.1567	70	71	0.1496	67	68	0.1428	65	65	0.1363	63	61
3700	0.1717	74	80	0.1637	71	74	0.1563	69	70	0.1493	67	67	0.1426	65	63
3800	0.1791	75	83	0.1708	73	76	0.1632	71	72	0.1560	68	69	0.1491	66	65
3900	0.1866	77	85	0.1781	75	78	0.1703	72	75	0.1628	70	71	0.1557	68	67
4000	0.1943	79	87	0.1856	77	81	0.1775	74	77	0.1698	72	73	0.1625	69	69
4100	0.2022	81	89	0.1933	78	84	0.1849	76	79	0.1770	73	76	0.1694	71	71
4200	0.2103	82	92	0.2011	79	86	0.1925	77	82	0.1843	74	78	0.1765	72	74
4300	0.2185	84	95	0.2090	81	88	0.2002	79	85	0.1917	77	80	0.1837	74	76
4400	0.2269	86	98	0.2171	83	90	0.2081	80	87	0.1994	78	83	0.1911	76	78
4500	0.2355	88	101	0.2254	84	93	0.2161	82	89	0.2072	80	85	0.1987	78	81
4600	0.2443	90	105	0.2338	87	95	0.2243	83	91	0.2152	81	87	0.2065	78	84
4700	0.2533	91	108	0.2425	89	99	0.2326	85	93	0.2233	82	90	0.2143	81	85
4800	0.2624	92	110	0.2514	90	103	0.2411	88	96	0.2315	85	91	0.2224	82	87
4900	0.2716	94	112	0.2604	91	105	0.2499	89	99	0.2400	86	94	0.2306	83	90
5000	0.2810	97	115	0.2695	94	107	0.2588	91	102	0.2486	89	97	0 2389	85	91
5100	0.2907	98	118	0.2789	95	110	0.2679	93	104	0.2575	90	101	0.2474	88	93
5200	0.3005	100	121	0.2884	97	112	0.2772	94	107	0.2665	92	103	0.2562	90	96
5300	0.3105	102	124	0.2981	99	115	0.2866	96	109	0.2757	93	105	0.2652	91	100
5400	0.3207	104	127	0.3080	100	118	0.2962	98	112	0.2850	95	107	0.2743	93	102
5500	0.3311	106	131	0.3180	103	120	0.3060	100	115	0.2945	97	109	0.2836	94	104
5600	0.3417	108	134	0.3283	104	123	0.3160	101	118	0.3042	99	112	0.2930	96	106
5700	0.3525	109	138	0.3387	107	126	0.3261	103	120	0.3141	100	115	0.3026	98	108
5800	0.3634	112	140	0.3494	109	130	0.3364	105	123	0.3241	103	117	0.3124	100	111
5900	0.3746	114	143	0.3603	110	134	0.3469	108	125	0.3344	105	120	0.3224	101	114
6000	0.3860	115	147	0.3713	113	136	0.3577	110	128	0.3449	105	124	0 3325	103	116
6100	0.3975	118	149	0.3826	114	139	0.3687	111	131	0.3554	109	126	0.3428	106	118
6200	0.4093	119	153	0.3940	116	142	0.3798	113	135	0.3663	110	129	0.3534	108	121
6300	0.4212	121	156	0.4056	118	145	0.3911	115	138	0.3773	112	131	0.3642	109	125
6400	0.4333	124	159	0.4174	120	148	0.4026	117	141	0.3885	115	134	0.3751	111	128
6500	0.4457	126	163	9.4294	122	151	0.4143	119	143	0.4000	115	138	0.3862	114	130

Digitized by Google

AUXILIARY TABLE B FOR SPHERICAL PROJECTILES—CONTINUED.

z.	1450.	Δ_2.	Δ_3.	1500.	Δ_2.	Δ_3.	1550.	Δ_2.	Δ_3.	1600.	Δ_2.	Δ_3.	1650.	Δ_2.	Δ_3.
3500	0.1243	59	56	0.1187	57	54	0.1133	55	51	0.1082	54	48	0.1034	52	47
3600	0.1302	61	58	0.1244	59	56	0.1188	58	52	0.1136	55	50	0.1086	53	48
3700	0.1363	63	60	0.1303	61	57	0.1246	58	55	0.1191	57	52	0.1139	56	49
3800	0.1426	64	62	0.1364	61	60	0.1304	61	56	0.1248	58	53	0.1195	56	52
3900	0.1490	66	65	0.1425	64	60	0.1365	61	59	0.1306	60	55	0.1251	58	53
4000	0.1556	67	67	0.1489	65	63	0.1426	63	60	0.1366	61	57	0.1309	60	55
4100	0.1623	68	69	0.1554	67	65	0.1489	65	62	0.1427	63	58	0.1369	61	57
4200	0.1691	70	70	0.1621	68	67	0.1554	66	64	0.1490	64	60	0.1430	62	59
4300	0.1761	72	72	0.1689	70	69	0.1620	68	66	0.1554	66	62	0.1492	63	60
4400	0.1833	73	74	0.1759	71	71	0.1688	69	68	0.1620	68	65	0.1555	66	61
4500	0.1906	75	76	0.1830	73	73	0.1757	71	69	0.1688	69	67	0.1621	67	64
4600	0.1981	77	78	0.1903	74	75	0.1828	72	71	0.1757	70	69	0.1688	69	65
4700	0.2058	79	81	0.1977	76	77	0.1900	74	73	0.1827	72	70	0.1757	70	68
4800	0.2137	79	84	0.2053	78	79	0.1974	76	75	0.1899	73	72	0.1827	72	70
4900	0.2216	82	85	0.2131	80	81	0.2050	77	78	0.1972	75	73	0.1899	73	72
5000	0.2298	83	87	0.2211	81	84	0.2127	79	80	0.2047	77	75	0.1972	74	73
5100	0.2381	85	89	0.2292	83	86	0.2206	81	82	0.2124	79	78	0.2046	77	74
5200	0.2466	86	91	0.2375	83	88	0.2287	82	84	0.2203	80	80	0.2123	78	77
5300	0.2552	89	94	0.2458	86	89	0.2369	84	86	0.2283	82	82	0.2201	79	78
5400	0.2641	91	97	0.2544	88	91	0.2453	85	88	0.2365	84	85	0.2280	82	80
5500	0.2732	92	100	0.2632	90	94	0.2538	87	89	0.2449	84	87	0.2362	84	82
5600	0.2824	94	102	0.2722	92	97	0.2625	89	92	0.2533	87	87	0.2446	84	85
5700	0.2918	95	104	0.2814	93	100	0.2714	92	94	0.2620	88	90	0.2530	86	87
5800	0.3013	97	106	0.2907	95	101	0.2806	92	98	0.2708	90	92	0.2616	88	88
5900	0.3110	99	108	0.3002	96	104	0.2898	94	100	0.2798	93	94	0.2704	89	90
6000	0.3209	101	111	0.3098	98	106	0.2992	96	101	0.2891	94	98	0.2793	93	92
6100	0.3310	103	114	0.3196	101	108	0.3088	98	103	0.2985	95	99	0.2886	94	96
6200	0.3413	104	116	0.3297	101	111	0.3186	100	106	0.3080	97	100	0.2980	95	98
6300	0.3517	106	119	0.3398	104	112	0.3286	101	109	0.3177	100	102	0.3075	96	99
6400	0.3623	109	121	0.3502	106	115	0.3387	103	110	0.3277	101	106	0.3171	99	100
6500	0.3732	111	124	0.3608	108	118	0.3490	106	112	0.3378	103	108	0.3270	101	103

Digitized by Google

AUXILIARY TABLE B FOR SPHERICAL PROJECTILES—CONTINUED.

s.	1700.	Δ_s.	Δ_v.	1750.	Δ_s.	Δ_v.
3500	0.0987	51	44	0.0943	49	-----
3600	0.1038	52	46	0.0992	50	-----
3700	0.1090	53	48	0.1042	53	-----
3800	0.1143	55	48	0.1095	53	-----
3900	0.1198	56	50	0.1148	54	-----
4000	0.1254	58	52	0.1202	57	-----
4100	0.1312	59	53	0.1259	57	-----
4200	0.1371	61	55	0.1316	59	-----
4300	0.1432	62	57	0.1375	60	-----
4400	0.1494	63	59	0.1435	62	-----
4500	0.1557	66	60	0.1497	63	-----
4600	0.1623	66	63	0.1560	65	-----
4700	0.1689	68	64	0.1625	67	-----
4800	0.1757	70	65	0.1692	68	-----
4900	0.1827	72	67	0.1760	70	-----
5000	0.1899	73	69	0.1830	70	-----
5100	0.1972	74	72	0.1900	73	-----
5200	0.2046	77	73	0.1973	75	-----
5300	0.2123	77	75	0.2048	75	-----
5400	0.2200	80	77	0.2123	78	-----
5500	0.2280	81	79	0.2201	80	-----
5600	0.2361	82	80	0.2281	80	-----
5700	0.2443	85	82	0.2361	83	-----
5800	0.2528	86	84	0.2444	84	-----
5900	0.2614	87	86	0.2528	86	-----
6000	0.2701	89	87	0.2614	87	-----
6100	.02790	92	89	0.2701	88	-----
6200	0.2882	94	93	0.2789	92	-----
6300	0.2976	95	95	0.2881	93	-----
6400	0.3071	96	97	0.2974	95	-----
6500	0.3167	98	98	0.3069	96	-----

Digitized by Google

AUXILIARY TABLE B FOR SPHERICAL PROJECTILES—CONTINUED.

z.	1200.	Δ_z.	Δ_v.	1250.	Δ_z.	Δ_v.	1300.	Δ_z.	Δ_v.	1350.	Δ_z.	Δ_v.	1400.	Δ_z.	Δ_v.
6500	0.4457	126	163	0.4294	122	151	0.4143	119	143	0.4000	115	138	0.3862	114	130
6600	0.4583	127	167	0.4416	124	154	0.4262	121	147	0.4115	118	139	0.3976	115	133
6700	0.4710	130	170	0.4540	126	157	0.4383	123	150	0.4233	120	142	0.4091	117	136
6800	0.4840	132	174	0.4666	129	160	0.4506	125	153	0.4353	122	145	0.4208	119	138
6900	0.4972	134	177	0.4795	130	164	0.4631	127	156	0.4475	124	148	0.4327	121	141
7000	0.5106	135	181	0.4925	133	167	0.4758	129	159	0.4599	126	151	0.4448	123	144
7100	0.5241	140	183	0.5058	136	171	0.4887	131	162	0.4725	128	154	0.4571	125	146
7200	0.5381	141	187	0.5194	136	176	0.5018	134	165	0.4853	131	157	0.4696	127	149
7300	0.5522	142	192	0.5330	139	178	0.5152	136	168	0.4984	132	161	0.4823	129	152
7400	0.5664	145	195	0.5469	142	181	0.5288	138	172	0.5116	135	164	0.4952	131	155
7500	0.5809	148	198	0.5611	143	185	0.5426	140	175	0.5251	137	168	0.5083	134	157
7600	0.5957	150	203	0.5754	145	188	0.5566	143	178	0.5388	139	171	0.5217	136	161
7700	0.6107	152	208	0.5899	148	190	0.5709	144	182	0.5527	141	174	0.5353	138	164
7800	0.6259	154	212	0.6047	151	194	0.5853	146	185	0.5668	143	177	0.5491	139	167
7900	0.6413	157	215	0.6198	152	199	0.5999	149	188	0.5811	145	181	0.5630	143	169
8000	0.6570	----	220	0.6350	----	202	0.6148	----	192	0.5956	----	183	0.5773	----	174

Digitized by Google

AUXILIARY TABLE B FOR SPHERICAL PROJECTILES—CONTINUED.

s.	1450.	Δ_s.	Δ_v.	1500.	Δ_s.	Δ_v.	1550.	Δ_s.	Δ_v.	1600.	Δ_s.	Δ_v.	1650.	Δ_s.	Δ_v.
6500	0.3732	111	124	0.3608	108	118	0.3490	106	112	0.3378	103	108	0.3270	101	103
6600	0.3843	112	127	0.3716	110	120	0.3596	107	115	0.3481	104	110	0.3371	104	106
6700	0.3955	115	129	0.3826	112	123	0.3703	109	118	0.3585	107	112	0.3473	105	108
6800	0.4070	116	132	0.3938	114	126	0.3812	111	120	0.3692	108	114	0.3578	106	111
6900	0.4186	118	134	0.4052	115	129	0.3923	113	123	0.3800	111	116	0.3684	108	112
7000	0.4304	121	137	0.4167	118	131	0.4036	115	125	0.3911	113	119	0.3792	110	115
7100	0.4425	122	140	0.4285	119	134	0.4151	117	127	0.4024	114	122	0.3902	112	117
7200	0.4547	124	143	0.4404	121	136	0.4268	119	130	0.4138	116	124	0.4014	114	120
7300	0.4671	126	146	0.4525	123	138	0.4387	121	133	0.4254	119	126	0.4128	116	122
7400	0.4797	129	149	0.4648	126	140	0.4508	123	135	0.4373	120	129	0.4244	118	124
7500	0.4926	130	152	0.4774	128	143	0.4631	124	138	0.4493	122	131	0.4362	119	127
7600	0.5056	133	154	0.4902	130	147	0.4755	127	140	0.4615	125	134	0.4481	122	128
7700	0.5189	135	157	0.5032	132	150	0.4882	129	142	0.4740	126	137	0.4603	124	131
7800	0.5324	137	160	0.5164	133	153	0.5011	131	145	0.4866	128	139	0.4727	125	134
7900	0.5461	138	164	0.5297	136	155	0.5142	134	148	0.4994	130	142	0.4852	128	135
8000	0.5599	----	166	0.5433	----	157	0.5276	----	152	0.5124	----	144	0.4980	----	138

Digitized by Google

AUXILIARY TABLE B FOR SPHERICAL PROJECTILES—CONTINUED.

s.	1700.	Δ_s.	Δ_v.	1750.	Δ_s.	Δ_v.
6500	0.3167	98	98	0.3069	96	-----
6600	0.3265	100	100	0.3165	98	-----
6700	0.3365	102	102	0.3263	100	-----
6800	0.3467	105	104	0.3363	102	-----
6900	0.3572	105	107	0.3465	103	-----
7000	0.3677	108	109	0.3568	105	-----
7100	0.3785	109	112	0.3673	108	-----
7200	0.3894	112	113	0.3781	109	-----
7300	0.4006	114	116	0.3890	111	-----
7400	0.4120	115	119	0.4001	114	-----
7500	0.4235	118	120	0.4115	114	-----
7600	0.4353	119	124	0 4229	118	-----
7700	0.4472	121	125	0.4347	119	-----
7800	0.4593	124	127	0.4466	121	-----
7900	0.4717	125	130	0.4587	123	-----
8000	0.4842	-----	132	0.4710	-----	-----

Digitized by Google

AUXILIARY TABLE M FOR SPHERICAL PROJECTILES.

s.	1200.	Δ_s.	Δ_v.	1250.	Δ_s.	Δ_v.	1300.	Δ_s.	Δ_v.	1350.	Δ_s.	Δ_v.	1400.	Δ_s.	Δ_v.
400	0.0192	53	14	0.0178	49	13	0.0165	46	12	0.0153	43	10	0.0143	39	10
500	0.0245	55	18	0.0227	51	16	0.0211	47	15	0.0196	43	14	0.0182	41	13
600	0.0300	56	22	0.0278	52	20	0.0258	49	19	0.0239	46	16	0.0223	43	16
700	0.0356	59	26	0.0330	56	23	0.0307	51	22	0.0285	48	19	0.0266	44	19
800	0.0415	60	29	0.0386	56	28	0.0358	53	25	0.0333	49	23	0.0310	46	20
900	0.0475	62	33	0.0442	58	31	0.0411	55	29	0.0382	52	26	0.0356	48	23
1000	0.0537	64	37	0.0500	61	34	0.0466	56	32	0.0434	54	30	0.0404	50	27
1100	0.0601	66	40	0.0561	61	39	0.0522	59	34	0.0488	54	34	0.0454	52	30
1200	0.0667	67	45	0.0622	64	41	0.0581	61	39	0.0542	57	36	0.0506	53	33
1300	0.0734	69	48	0.0686	65	44	0.0642	62	43	0.0599	59	40	0.0559	56	36
1400	0.0803	71	52	0.0751	67	47	0.0704	64	46	0.0658	60	43	0.0615	58	40
1500	0.0874	73	56	0.0818	69	50	0.0768	65	50	0.0718	63	45	0.0673	58	43
1600	0.0957	75	60	0.0887	71	54	0.0833	67	52	0.0781	64	50	0.0731	61	46
1700	0.1022	78	64	0.0958	75	58	0.0900	69	55	0.0845	65	53	0.0792	63	49
1800	0.1100	79	67	0.1033	75	64	0.0969	71	59	0.0910	68	55	0.0855	64	52
1900	0.1179	82	71	0.1108	78	68	0.1040	74	62	0.0978	70	59	0.0919	66	55
2000	0.1261	84	75	0.1186	78	72	0.1114	76	66	0.1048	72	63	0.0985	68	57
2100	0.1345	85	81	0.1264	82	74	0.1190	77	70	0.1110	74	67	0.1053	71	61
2200	0.1430	88	84	0.1346	83	79	0.1267	80	73	0.1194	74	70	0.1124	72	65
2300	0.1518	91	89	0.1429	84	82	0.1347	82	79	0.1268	79	72	0.1196	74	69
2400	0.1609	91	96	0.1513	89	84	0.1429	83	82	0.1347	80	77	0.1270	76	72
2500	0.1700	93	98	0.1602	90	90	0.1512	85	85	0.1427	82	81	0.1346	78	75
2600	0.1793	95	101	0.1692	92	95	0.1597	88	88	0.1509	82	85	0.1424	81	78
2700	0.1888	100	104	0.1784	93	99	0.1685	90	94	0.1591	87	86	0.1505	82	83
2800	0.1988	100	111	0.1877	95	102	0.1775	92	97	0.1678	89	91	0.1587	84	86
2900	0.2088	102	116	0.1972	99	105	0.1867	94	100	0.1767	90	96	0.1671	86	89
3000	0.2190	105	119	0.2071	100	110	0.1961	95	104	0.1857	91	100	0.1757	89	92
3100	0.2295	108	124	0.2171	102	115	0.2056	99	108	0.1948	95	102	0.1846	90	97
3200	0.2403	109	130	0.2273	106	118	0.2155	100	112	0.2043	96	107	0.1936	92	100
3300	0.2512	112	133	0.2379	106	124	0.2255	103	116	0.2139	99	111	0.2028	96	102
3400	0.2624	113	139	0.2485	111	127	0.2358	106	120	0.2238	100	114	0.2124	96	107
3500	0.2737	116	141	0.2596	111	132	0.2464	107	126	0.2338	103	118	0.2220	99	110

Digitized by Google

AUXILIARY TABLE M FOR SPHERICAL PROJECTILES—CONTINUED.

z.	1450.	Δ_z.	Δ_v.	1500.	Δ_z.	Δ_v.	1550.	Δ_z.	Δ_v.	1600.	Δ_z.	Δ_v.	1650.	Δ_z.	Δ_v.
400	0.0133	36	9	0.0124	34	8	0.0116	32	7	0.0109	30	7	0.0102	29	5
500	0.0169	38	11	0.0158	36	10	0.0148	34	9	0.0139	32	8	0.0131	29	8
600	0.0207	40	13	0.0194	37	12	0.0182	35	11	0.0171	32	11	0.0160	31	9
700	0.0247	43	16	0.0231	39	14	0.0217	36	14	0.0203	34	12	0.0191	32	11
800	0.0290	43	20	0.0270	41	17	0.0253	38	16	0.0237	36	14	0.0223	34	13
900	0.0333	44	22	0.0311	42	20	0.0291	39	18	0.0273	37	16	0.0257	34	16
1000	0.0377	47	24	0.0353	44	23	0.0330	41	20	0.0310	38	19	0.0291	37	17
1100	0.0424	49	27	0.0397	45	26	0.0371	42	23	0.0348	40	20	0.0328	38	20
1200	0.0473	50	31	0.0442	47	29	0.0413	45	25	0.0388	42	22	0.0366	39	23
1300	0.0523	52	34	0.0489	49	31	0.0458	46	28	0.0430	44	25	0.0405	41	24
1400	0.0575	55	37	0.0538	51	34	0.0504	48	30	0.0474	45	28	0.0446	43	26
1500	0.0630	55	41	0.0589	53	37	0.0552	50	33	0.0519	47	30	0.0489	44	29
1600	0.0685	58	43	0.0642	55	40	0.0602	52	36	0.0566	49	33	0.0533	46	31
1700	0.0743	60	46	0.0697	57	43	0.0654	54	39	0.0615	50	36	0.0579	47	34
1800	0.0803	61	49	0.0754	58	46	0.0708	56	43	0.0665	53	39	0.0626	50	35
1900	0.0864	64	52	0.0812	60	48	0.0764	57	46	0.0718	55	42	0.0676	52	39
2000	0.0928	64	56	0.0872	62	51	0.0821	59	48	0.0773	56	45	0.0728	54	42
2100	0.0992	67	58	0.0934	64	54	0.0880	61	51	0.0829	58	47	0.0782	55	45
2200	0.1059	68	61	0.0998	65	57	0.0941	63	54	0.0887	60	50	0.0837	57	48
2300	0.1127	71	64	0.1063	67	59	0.1004	64	57	0.0947	62	53	0.0894	59	50
2400	0.1198	73	68	0.1130	69	62	0.1068	66	59	0.1009	63	56	0.0953	60	52
2500	0.1271	75	72	0.1199	72	65	0.1134	68	62	0.1072	65	59	0.1013	63	55
2600	0.1346	76	75	0.1271	74	69	0.1202	70	65	0.1137	67	61	0.1076	64	58
2700	0.1422	79	77	0.1345	75	73	0.1272	72	68	0.1204	69	64	0.1140	66	60
2800	0.1501	81	81	0.1420	77	76	0.1344	74	71	0.1273	71	67	0.1206	68	63
2900	0.1582	83	85	0.1497	80	79	0.1418	76	74	0.1344	73	70	0.1274	70	65
3000	0.1665	84	88	0.1577	82	83	0.1494	78	77	0.1417	75	73	0.1344	72	68
3100	0.1749	87	90	0.1659	82	87	0.1572	81	80	0.1492	76	76	0.1416	75	71
3200	0.1836	90	95	0.1741	85	88	0.1653	82	85	0.1568	80	77	0.1491	75	75
3300	0.1926	91	100	0.1826	88	91	0.1735	83	87	0.1648	81	82	0.1566	78	77
3400	0.2017	93	103	0.1914	91	96	0.1818	87	89	0.1729	83	85	0.1644	81	80
3500	0.2110	95	105	0.2005	91	100	0.1905	89	93	0.1812	85	87	0.1725	82	84

Digitized by Google

AUXILIARY TABLE M FOR SPHERICAL PROJECTILES—CONTINUED.

s.	1700.	Δ_s.	Δ_v.	1750.	Δ_s.	Δ_v.
400	0.0097	26	6	0.0091	25	-----
500	0.0123	28	7	0.0116	27	-----
600	0.0151	29	8	0.0143	27	-----
700	0.0180	30	10	0.0170	29	-----
800	0.0210	31	11	0.0199	29	-----
900	0.0241	33	13	0.0228	31	-----
1000	0.0274	34	15	0.0259	33	-----
1100	0.0308	35	16	0.0292	33	-----
1200	0.0343	38	18	0.0325	35	-----
1300	0.0381	39	21	0.0360	36	-----
1400	0.0420	40	24	0.0396	38	-----
1500	0.0460	42	26	0.0434	40	-----
1600	0.0502	43	28	0.0474	41	-----
1700	0.0545	46	30	0.0515	43	-----
1800	0.0591	46	33	0.0558	44	-----
1900	0.0637	49	35	0.0602	46	-----
2000	0.0686	51	38	0.0648	48	-----
2100	0.0737	52	41	0.0696	50	-----
2200	0.0789	55	43	0.0746	52	-----
2300	0.0844	57	46	0.0798	54	-----
2400	0.0901	57	49	0.0852	56	-----
2500	0.0958	60	50	0.0908	56	-----
2600	0.1018	62	54	0.0964	60	-----
2700	0.1080	63	56	0.1024	60	-----
2800	0.1143	66	59	0.1084	64	-----
2900	0.1209	67	61	0.1148	64	-----
3000	0.1276	69	64	0.1212	66	-----
3100	0.1345	71	67	0.1278	68	-----
3200	0.1416	73	70	0.1346	70	-----
3300	0.1489	75	73	0.1416	73	-----
3400	0.1564	77	75	0.1489	74	-----
3500	0.1641	79	78	0.1563	76	-----

Digitized by Google

AUXILIARY TABLE M FOR SPHERICAL PROJECTILES—CONTINUED.

z.	1200.	Δ_z.	Δ_v.	1250.	Δ_z.	Δ_v.	1300.	Δ_z.	Δ_v.	1350.	Δ_z.	Δ_v.	1400.	Δ_z.	Δ_v.
3500	0.2737	116	141	0.2596	111	132	0.2464	107	126	0.2338	103	118	0.2220	99	110
3600	0.2853	119	146	0.2707	114	136	0.2571	109	130	0.2441	107	122	0.2319	101	114
3700	0.2972	121	151	0.2821	115	141	0.2680	111	132	0.2548	107	128	0.2420	104	118
3800	0.3093	123	157	0.2936	118	145	0.2791	115	136	0.2655	109	131	0.2524	106	121
3900	0.3216	125	162	0.3054	122	148	0.2906	115	142	0.2764	112	134	0.2630	109	126
4000	0.3341	128	165	0.3176	123	155	0.3021	119	145	0.2876	115	137	0.2739	109	130
4100	0.3469	130	170	0.3299	126	159	0.3140	122	149	0.2991	116	143	0.2848	113	132
4200	0.3599	133	174	0.3425	127	163	0.3262	123	155	0.3107	119	146	0.2961	114	137
4300	0.3732	135	180	0.3552	130	167	0.3385	126	159	0.3226	122	151	0.3075	117	141
4400	0.3867	138	185	0.3682	132	171	0.3511	128	163	0.3348	123	156	0.3192	120	145
4500	0.4005	141	191	0.3814	135	175	0.3639	130	168	0.3471	127	159	0.3312	123	150
4600	0.4146	144	197	0.3949	138	180	0.3769	132	171	0.3598	128	163	0.3435	123	155
4700	0.4290	145	203	0.4087	141	186	0.3901	135	175	0.3726	130	168	0.3558	127	157
4800	0.4435	147	207	0.4228	143	192	0.4036	138	180	0.3856	133	171	0.3685	129	161
4900	0.4582	150	211	0.4371	145	197	0.4174	141	185	0.3989	135	175	0.3814	130	166
5000	0.4732	153	216	0.4516	148	201	0.4315	143	191	0.4124	140	180	0.3944	133	168
5100	0.4885	156	221	0.4664	150	206	0.4458	146	194	0.4264	141	187	0.4077	137	172
5200	0.5041	157	227	0.4814	153	210	0.4604	148	199	0.4405	144	191	0.4214	140	178
5300	0.5198	162	231	0.4967	155	215	0.4752	150	203	0.4549	145	195	0.4354	142	184
5400	0.5360	163	238	0.5122	157	220	0.4902	153	208	0.4694	148	198	0.4496	144	188
5500	0.5523	167	244	0.5279	162	224	0.5055	156	213	0.4842	150	202	0.4640	145	192
5600	0.5690	169	249	0.5441	163	230	0.5211	158	219	0.4992	154	207	0.4785	149	195
5700	0.5859	172	255	0.5604	166	235	0.5369	161	223	0.5146	156	212	0.4934	151	199
5800	0.6031	175	261	0.5770	170	240	0.5530	163	228	0.5302	159	217	0.5085	155	204
5900	0.6206	178	266	0.5940	172	247	0.5693	167	232	0.5461	162	221	0.5240	156	209
6000	0.6384	180	272	0.6112	176	252	0.5860	170	237	0.5623	163	227	0.5396	159	213
6100	0.6564	184	276	0.6288	177	258	0.6030	173	244	0.5786	168	231	0.5555	162	217
6200	0.6748	185	283	0.6465	179	262	0.6203	174	249	0.5954	169	237	0.5717	165	222
6300	0.6933	188	289	0.6644	184	267	0.6377	178	254	0.6123	173	241	0.5882	168	227
6400	0.7121	192	293	0.6828	185	273	0.6555	179	259	0.6296	176	246	0.6050	170	233
6500	0.7313	195	300	0.7013	188	279	0.6734	184	262	0.6472	177	252	0.6220	174	237

Digitized by Google

AUXILIARY TABLE M FOR SPHERICAL PROJECTILES—CONTINUED.

z.	1450.	Δ_z.	Δ_v.	1500.	Δ_z.	Δ_v.	1550.	Δ_z.	Δ_v.	1600.	Δ_z.	Δ_v.	1650.	Δ_z.	Δ_v.
3500	0.2110	95	105	0.2005	91	100	0.1905	89	93	0.1812	85	87	0.1725	82	84
3600	0.2205	97	109	0.2096	94	102	0.1994	91	97	0.1897	87	90	0.1807	83	87
3700	0.2302	101	112	0.2190	96	105	0.2085	92	101	0.1984	90	94	0.1890	87	88
3800	0.2403	101	117	0.2286	98	109	0.2177	95	103	0.2074	91	97	0.1977	88	93
3900	0.2504	105	120	0.2384	101	112	0.2272	97	107	0.2165	94	100	0.2065	91	96
4000	0.2609	107	124	0.2485	102	116	0.2369	99	110	0.2259	95	103	0.2156	92	99
4100	0.2716	108	129	0.2587	106	119	0.2468	101	114	0.2354	98	106	0.2248	95	101
4200	0.2824	110	131	0.2693	107	124	0.2569	104	117	0.2452	100	109	0.2343	96	105
4300	0.2934	113	134	0.2800	110	127	0.2673	106	121	0.2552	103	113	0.2439	99	108
4400	0.3047	115	137	0.2910	111	131	0.2779	108	124	0.2655	105	117	0.2538	101	111
4500	0.3162	118	141	0.3021	114	134	0.2887	110	127	0.2760	107	121	0.2639	104	114
4600	0.3280	121	145	0.3135	115	138	0.2997	112	130	0.2867	109	124	0.2743	106	118
4700	0.3401	123	151	0.3250	119	141	0.3109	115	133	0.2976	111	127	0.2849	108	122
4800	0.3524	124	155	0.3369	121	145	0.3224	117	137	0.3087	113	130	0.2957	110	125
4900	0.3648	128	158	0.3490	124	149	0.3341	120	141	0.3200	115	133	0.3067	112	128
5000	0.3776	129	162	0.3614	126	153	0.3461	122	146	0.3315	118	136	0.3179	114	131
5100	0.3905	131	165	0.3740	128	157	0.3583	124	150	0.3433	122	140	0.3293	117	133
5200	0.4036	134	168	0.3868	129	161	0.3707	127	152	0.3555	122	145	0.3410	119	138
5300	0.4170	138	173	0.3997	132	163	0.3834	129	157	0.3677	126	148	0.3529	122	140
5400	0.4308	140	179	0.4129	136	166	0.3963	130	160	0.3803	128	152	0.3651	124	145
5500	0.4448	142	183	0.4265	138	172	0.4093	133	162	0.3931	129	156	0.3775	127	147
5600	0.4590	145	187	0.4403	142	177	0.4226	137	166	0.4060	132	158	0.3902	129	152
5700	0.4735	146	190	0.4545	142	182	0.4363	140	171	0.4192	134	161	0.4031	130	155
5800	0.4881	150	194	0.4687	145	184	0.4503	141	177	0.4326	138	165	0.4161	133	157
5900	0.5031	152	199	0.4832	148	188	0.4644	144	180	0.4464	141	170	0.4294	136	161
6000	0.5183	155	203	0.4980	150	192	0.4788	145	183	0.4605	142	175	0.4430	140	165
6100	0.5338	157	208	0.5130	153	197	0.4933	149	186	0.4747	145	177	0.4570	142	171
6200	0.5495	160	212	0.5283	155	201	0.5082	152	190	0.4892	146	180	0.4712	143	175
6300	0.5655	162	217	0.5438	158	204	0.5134	154	196	0.5038	151	183	0.4855	145	177
6400	0.5817	166	221	0.5596	161	208	0.5388	156	199	0.5189	153	189	0.5000	149	179
6500	0.5983	169	226	0.5757	164	213	0.5544	160	202	0.5342	155	193	0.5149	152	184

Digitized by Google

AUXILIARY TABLE M FOR SPHERICAL PROJECTILES—CONTINUED.

s.	1700.	Δ_s.	Δ_v.	1750.	Δ_s.	Δ_v.
3500	0.1641	79	78	0.1563	76	-----
3600	0.1720	82	81	0.1639	78	-----
3700	0.1802	82	85	0.1717	81	-----
3800	0.1884	85	86	0.1798	82	-----
3900	0.1969	88	89	0.1880	84	-----
4000	0.2057	90	93	0.1964	87	-----
4100	0.2147	91	96	0.2051	89	-----
4200	0.2238	93	98	0.2140	91	-----
4300	0.2331	96	100	0.2231	91	-----
4400	0.2427	98	105	0.2322	95	-----
4500	0.2525	100	108	0.2417	97	-----
4600	0.2625	102	111	0.2514	99	-----
4700	0.2727	105	114	0.2613	102	-----
4800	0.2832	107	117	0.2715	104	-----
4900	0.2939	109	120	0.2819	106	-----
5000	0.3048	112	123	0.2925	108	-----
5100	0.3160	112	127	0.3033	110	-----
5200	0.3272	117	129	0.3143	113	-----
5300	0.3389	117	133	0.3256	114	-----
5400	0.3506	122	136	0.3370	117	-----
5500	0.3628	122	141	0.3487	121	-----
5600	0.3750	126	142	0.3608	121	-----
5700	0.3876	128	147	0.3729	125	-----
5800	0.4004	129	150	0.3854	127	-----
5900	0.4133	132	152	0.3981	129	-----
6000	0.4265	134	155	0.4110	130	-----
6100	0.4399	138	159	0.4240	133	-----
6200	0.4537	141	164	0.4373	137	-----
6300	0.4678	143	168	0.4510	140	-----
6400	0.4821	144	171	0.4650	142	-----
6500	0.4965	147	173	0.4792	143	-----

Digitized by Google

AUXILIARY TABLE M FOR SPHERICAL PROJECTILES—CONTINUED.

z.	1200.	Δ_z.	Δ_v.	1250.	Δ_z.	Δ_v.	1300.	Δ_z.	Δ_v.	1350.	Δ_z.	Δ_v.	1400.	Δ_z.	Δ_v.
6500	0.7313	195	300	0.7013	188	279	0.6734	184	262	0.6472	177	252	0.6220	174	237
6600	0.7508	197	307	0.7201	192	283	0.6918	186	269	0.6649	181	255	0.6394	176	242
6700	0.7705	201	312	0.7393	194	289	0.7104	189	274	0.6830	184	260	0.6570	178	247
6800	0.7906	203	319	0.7587	198	294	0.7293	192	279	0.7014	185	266	0.6748	181	251
6900	0.8109	207	324	0.7785	200	300	0.7485	194	286	0.7199	190	270	0.6929	185	255
7000	0.8316	209	331	0.7985	203	306	0.7679	198	290	0.7389	192	275	0.7114	186	261
7100	0.8525	214	337	0.8188	208	311	0.7877	200	296	0.7581	195	281	0.7300	190	264
7200	0.8739	217	343	0.8396	209	319	0.8077	204	301	0.7776	199	286	0.7490	192	270
7300	0.8956	217	351	0.8605	213	324	0.8281	207	306	0.7975	201	293	0.7682	196	274
7400	0.9173	222	355	0.8818	216	330	0.8488	210	312	0.8176	204	298	0.7878	199	280
7500	0.9395	226	361	0.9034	218	336	0.8698	213	318	0.8380	207	303	0.8077	202	285
7600	0.9621	229	369	0.9252	222	341	0.8911	217	324	0.8587	211	308	0.8279	205	291
7700	0.9850	232	376	0.9474	225	346	0.9128	218	330	0.8798	214	314	0.8484	208	296
7800	1.0082	235	383	0.9699	229	353	0.9346	221	334	0.9012	216	320	0.8692	211	301
7900	1.0317	239	389	0.9928	230	361	0.9567	226	339	0.9228	218	325	0.8903	214	306
8000	1.0556	----	398	1.0158	----	365	0.9793	----	347	0.9446	----	329	0.9117	----	312

Digitized by Google

AUXILIARY TABLE M FOR SPHERICAL PROJECTILES—CONTINUED.

s.	1450.	Δ_s.	Δ_v.	1500.	Δ_s.	Δ_v.	1550.	Δ_s.	Δ_v.	1600.	Δ_s.	Δ_v.	1650.	Δ_s.	Δ_v.
6500	0.5983	169	226	0.5757	164	213	0.5544	160	202	0.5342	155	193	0.5149	152	184
6600	0.6152	171	231	0.5921	167	217	0.5704	162	207	0.5497	157	196	0.5301	155	189
6700	0.6323	174	235	0.6088	169	222	0.5866	165	212	0.5654	161	200	0.5454	157	192
6800	0.6497	177	240	0.6257	173	226	0.6031	167	216	0.5815	162	204	0.5611	159	196
6900	0.6674	179	244	0.6430	174	232	0.6198	170	221	0.5977	167	207	0.5770	162	199
7000	0.6853	183	249	0.6604	178	236	0.6368	174	224	0.6144	169	212	0.5932	164	204
7100	0.7036	184	254	0.6782	179	240	0.6542	176	229	0.6313	172	217	0.6096	168	207
7200	0.7220	188	259	0.6961	184	243	0.6718	178	233	0.6485	174	221	0.6264	170	213
7300	0.7408	190	263	0.7145	185	249	0.6896	182	237	0.6659	178	225	0.6434	173	216
7400	0.7598	194	268	0.7330	189	252	0.7078	184	241	0.6837	179	230	0.6607	176	220
7500	0.7792	196	273	0.7519	192	257	0.7262	186	246	0.7016	183	233	0.6783	178	224
7600	0.7988	200	277	0.7711	195	263	0.7448	190	249	0.7199	185	238	0.6961	181	227
7700	0.8188	203	282	0.7906	198	268	0.7638	193	254	0.7384	188	242	0.7142	184	232
7800	0.8391	206	287	0.8104	199	273	0.7831	196	259	0.7572	191	246	0.7326	186	236
7900	0.8597	208	294	0.8303	204	276	0.8027	199	264	0.7763	194	251	0.7512	190	239
8000	0.8805	----	298	0.8507	----	281	0.8226	----	269	0.7957	----	255	0.7702	----	244

Digitized by Google

AUXILIARY TABLE M FOR SPHERICAL PROJECTILES—CONTINUED.

s.	1700.	Δ_s.	Δ_v.	1750.	Δ_s.	Δ_v.
6500	0.4965	147	173	0.4792	143	-----
6600	0.5112	150	177	0.4935	146	-----
6700	0.5262	153	181	0.5081	149	-----
6800	0.5415	156	185	0.5230	152	-----
6900	0.5571	157	189	0.5382	154	-----
7000	0.5728	161	192	0.5536	156	-----
7100	0.5889	162	197	0.5692	160	-----
7200	0.6051	167	199	0.5852	162	-----
7300	0.6218	169	204	0.6014	165	-----
7400	0.6387	172	208	0.6179	168	-----
7500	0.6559	175	212	0.6347	170	-----
7600	0.6734	176	217	0.6517	174	-----
7700	0.6910	180	219	0.6691	176	-----
7800	0.7090	183	223	0.6867	178	-----
7900	0.7273	185	228	0.7045	182	----
8000	0.7458	-----	231	0.7227	-----	-----

20634——17

Digitized by Google

Digitized by Google

TABLE III.

Values of $\frac{\delta'}{\delta}$ for temperature and pressure of atmosphere two-thirds saturated with moisture.

F.	28 inches.	29 inches.	30 inches.	31 inches.	F.	28 inches.	29 inches.	30 inches.	31 inches.
°					°				
0	0.945	0.912	0.882	0.853	28	1.004	0.969	0.937	0.907
1	0.947	0.914	0.884	0.855	29	1.006	0.971	0.939	0.909
2	0.949	0.916	0.886	0.857	30	1.008	0.973	0.941	0.911
3	0.951	0.918	0.888	0.859					
					31	1.010	0.975	0.943	0.912
4	0.953	0.920	0.890	0.861	32	1.012	0.977	0.945	0.914
5	0.955	0.922	0.892	0.863	33	1.014	0.979	0.947	0.916
6	0.957	0.924	0.893	0.865					
					34	1.016	0.981	0.949	0.918
7	0.959	0.926	0.895	0.867	35	1.018	0.983	0.951	0.920
8	0.962	0.928	0.897	0.869	36	1.021	0.986	0.953	0.922
9	0.964	0.930	0.899	0.870					
					37	1.023	0.988	0.955	0.924
10	0.966	0.932	0.901	0.872	38	1.025	0.990	0.957	0.926
11	0.968	0.935	0.903	0.874	39	1.027	0.992	0.958	0.928
12	0.970	0.937	0.905	0.876					
					40	1.029	0.994	0.960	0.930
13	0.972	0.939	0.907	0.878	41	1.031	0.996	0.962	0.932
14	0.974	0.941	0.909	0.880	42	1.033	0.998	0.964	0.933
15	0.976	0.943	0.911	0.882					
					43	1.035	1.000	0.966	0.935
16	0.978	0.945	0.913	0.884	44	1.037	1.002	0.968	0.937
17	0.981	0.947	0.915	0.886	45	1.040	1.004	0.970	0.939
18	0.983	0.949	0.917	0.888					
					46	1.042	1.006	0.972	0.941
19	0.985	0.951	0.919	0.890	47	1.044	1.008	0.974	0.943
20	0.987	0.953	0.921	0.891	48	1.046	1.010	0.976	0.945
21	0.989	0.955	0.923	0.893					
					49	1.048	1.012	0.978	0.947
22	0.991	0.957	0.925	0.895	50	1.050	1.014	0.980	0.949
23	0.993	0.959	0.927	0.897	51	1.052	1.016	0.982	0.951
24	0.995	0.961	0.929	0.899					
					52	1.054	1.018	0.984	0.953
25	0.997	0.963	0.931	0.901	53	1.056	1.020	0.986	0.954
26	1.000	0.965	0.933	0.903	54	1.058	1.022	0.988	0.956
27	1.002	0.967	0.935	0.905					

Digitized by Google

TABLE III—CONTINUED.

F.	28 inches.	29 inches.	30 inches.	31 inches.	F.	28 inches.	29 inches.	30 inches.	31 inches.
°					°				
55	1.061	1.024	0.990	0.958	78	1.109	1.071	1.035	1.002
56	1.063	1.026	0.992	0.960	79	1.111	1.073	1.037	1.004
57	1.065	1.028	0.994	0.962	80	1.113	1.075	1.039	1.006
58	1.067	1.030	0.996	0.964	81	1.116	1.077	1.041	1.008
59	1.069	1.032	0.998	0.966	82	1.118	1.079	1.043	1.010
60	1.071	1.034	1.000	0.968	83	1.120	1.081	1.045	1.012
61	1.073	1.037	0.002	0.970	84	1.122	1.083	1.047	1.014
62	1.075	1.039	1.004	0.972	85	1.124	1.085	1.049	1.016
63	1.078	1.041	1.006	0.974	86	1.126	1.088	1.051	1.017
64	1.080	1.043	1.008	0.975	87	1.128	1.090	1.053	1.019
65	1.082	1.045	1.010	0.977	88	1.130	1.092	1.055	1.021
66	1.084	1.047	1.012	0.979	89	1.132	1.094	1.057	1.023
67	1.086	1.049	1.014	0.981	90	1.135	1.096	1.059	1.025
68	1.088	1.051	1.016	0.983	91	1.137	1.098	1.061	1.027
69	1.090	1.053	1.018	0.985	92	1.139	1.100	1.063	1.029
70	1.092	1.055	1.020	0.987	93	1.141	1.102	1.065	1.031
71	1.094	1.057	1.022	0.989	94	1.143	1.104	1.067	1.033
72	1.097	1.059	1.024	0.991	95	1.145	1.106	1.069	1.035
73	1.099	1.061	1.025	0.993	96	1.147	1.108	1.071	1.037
74	1.101	1.063	1.027	0.995	97	1.149	1.110	1.073	1.038
75	1.103	1.065	1.029	0.996	98	1.151	1.112	1.075	1.040
76	1.105	1.067	1.031	0.998	99	1.155	1.114	1.077	1.042
77	1.107	1.069	1.033	1.000	100	1.157	1.116	1.079	1.044

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Stanford University Libraries
3 6105 122 886 448

Digitized by Google